Compendium

by armada

Naval Robotics

swimming in uncertain waters

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CLARION EVENTS

The Double Eagle, here a MkIII, can be equipped with a manipulator arm, but can carry all manner of sensors and sonars either in belly centreline position or cross-mounted under its chin. (Saab)

Swimming in Uncertain Waters

Underwater, there is an established and growing mission set that includes mine hunting and disposal, battlespace preparation, 3D mapping, lost object recovery, payload deployment and recovery, ship hull, harbour, port and underwater infrastructure inspection, with new missions such as submarine track and trail taking shape. The least well developed sector - described in a 2013 RAND report as vigorous but narrow - is that of USVs, with most focused on observation and information collection, characterisation of the physical environment.

Peter Donaldson, inputs from Eric H. Biass

Although navies have used robotic systems of many kinds at sea for decades, vast untapped potential remains and analysts are beginning to regard the sector as the next focus of potentially disruptive technologies. "The most significant advances or changes to existing force structure involving substitution of unmanned systems in the near term will likely come on the ground, at sea, and undersea", wrote Samuel J Brannen, lead author of Sustaining the US Lead in Unmanned Systems, a report published in February 2014 by the Centre for Strategic and International Studies (CSIS), which regards such advances as potentially double edged for the United States. "The Navy has moved slowly in the development of unmanned surface vehicles (USVs), but is clearly committed to exploring the capabilities of unmanned underwater vehicles (UUVs), including its ongoing experimentation with the large-displacement UUV. The technology is potentially transformative in undersea warfare, including as a disruptive technology that could erode the United States' asymmetric advantage in the domain." Keen to ensure that this does not happen, Chief of Naval operations Admiral Jonathan Greenert put a roadmap with milestones to advance the technology among his top priorities for 2014.

SURFACE

In its analysis, RAND found three opportunities for the use of surface vehicle systems that it describes as "mission-transcendent". The first of these exploits their contact with the underwater and air domains to facilitate communication between them,

Described by RAND as "vigorous but narrow", development of USVs is predominantly focused on observation, information collection and environmental characterisation. This experimental US Navy Powervent vessel added non-lethal weapons in the 2012 Trident Warrior event. (US Navy)

also gaining leverage from relatively large payloads, reserves of power and long endurance to provide services such as transport, launch and recovery and electrical power for other unmanned vehicles. The second hinges on their potential to operate successfully anti-access/area denial (A2/AD) strategies by reducing risks to humans and large capital assets; "dispersing capabilities into small, hard-to-target nodes and expanding tactical choices by creating new concepts of employment." Thirdly, RAND concluded that more investment in research and development could lead to transfer of useful new technologies to other manned and unmanned systems.

RAND also concluded that advances in autonomy and assured communications are critical for the ability of surface systems to conduct complex missions, particularly in complex environments, further arguing that levels of mission/environmental complexity and requirements for autonomy and assured communications are related in a "control triangle" analogous to the "iron triangle" - familiar to naval architects – of speed, payload and endurance.

RAND cites sea keeping and surface traffic avoidance and general obedience to the maritime rules of the road, pointing out that advances in this area could subsequently benefit manned platforms by, for example, reducing the number of people needed for watch standing duties.

RAND also picked out some useful approaches to robotic surface vehicles development, such as developing standard platforms and modular payloads; furthering optional manning for benign environments and for missions in which a human crew would be desirable; making the post of their long endurance potential by designing for reliability and developing optionally manned refuelling, data transfer and maintenance vessels to support them and enabling them to scavenge energy from the environment to run modes and systems with small power requirements.

"The think tank also flagged up some of the challenges to be faced in maturing an overarching unmanned vehicle capability. Firstly, as integrated systems, unmanned systems are not unmanned; the only part that contains no humans is the vehicle itself."

The think tank also flagged up some of the challenges to be faced in maturing an overarching uninhabited vehicle capability. Firstly, as integrated systems, unmanned systems are not unmanned; the only part that contains no humans is the vehicle itself. Operations with current technologies have shown that the numbers required to operate and support a drone system exceeds that for a "normal aircraft" with a comparable concept of employment. Also, because they will augment rather than replace traditional aircraft, they are likely to increase investment costs, at least in the short term, an issue exacerbated by the fact that the so-called USVs will be able to perform some but not all of the missions of a large manned warship, and certainly not all at the same time. Furthermore, systems that can't self-deploy will need transport.

Several autonomous or remote-controlled speedboats have been developed in recent years, a field in which again Israel excels, as exemplified by Rafael and its rigid-hull inflatable boat –based Protector series which are in use in Israel and Singapore, but which have also been extensively tested under the

MCM in general and minehunting in particular is one of the established mission sets for naval robotics and the Lockheed Martin Remote Minehunting System is central to the LCS MCM mission set. Here, the diesel-engined submersible is launched carrying an AQS-20A towed sonar. (US Navy)

leadership of Lockheed Martin in the United States for potential use by the Coast Guards.

Still from Israel and named after the Samurais' sword (which clearly means business), the Katana is IAI's latest development in the field of autonomous speedboats. IAI is no newcomer in uninhabited systems, and not only in drones but also land robotics – see our compendium on this subject published with this issue of Armada International. Quite clearly based on hull designed by high speed patrol and leisure boat specialist Fabio Buzzi Design easily able to reach speeds of over 65 knots (120 km/h) the Katana was launched in February 2014. In the pictures supplied by IAI, no weapons are visible, but there is every reason to believe that these could be incorporated to customer requirement. Quite visible on the forward deck though are self protection grenade launchers, while flanked by various antennae a Tamam Mini Pop-based stabilised electro-optical sphere rests on the upper shelf of the aft structure – a commanding position that is least affected by the vertical plane rotations of the hull. Just below it is a maritime navigation radar. According to IAI the Katana is capable of autonomous navigation and to this end incorporates an obstacle avoidance system and a beyond line-of-sight communications system.

Underwater, the biggest challenges are different. Lack of access to atmospheric air makes achieving long endurance while storing enough energy to run demanding payloads very difficult. One solution resonates with non-nuclear submarine practice of combining a snorkel-fed internal combustion engine with batteries for example to produce a vehicle with limited underwater endurance but much longer mission endurance thanks to the ability to recharge at the surface. Another approach is to use a very low energy propulsion system, particularly where endurance is at a much higher premium than speed.

GLIDERS RULE ENDURANCE MISSIONS

One of the most promising types, the buoyancy driven glider, does exactly this and is carving itself a growing niche in both scientific and military operations. Needing neither a propeller nor movable control surfaces, gliders use an electric pump to transfer oil between two chambers, one inside and one outside the pressure hull to change the vehicle's density relative to the water around it and thus its buoyancy.

As it rises or sinks in the water, wings generate a positive or negative lift vector that propels the vehicle forward. By tilting the battery pack laterally inside the hull, the control system rolls the vehicle left or right to steer it. This is a very slow but very energy-efficient means of propulsion that enables gliders to stay at sea for months travelling, as a rule of thumb, at "half a knot on half a Watt". Burst communication via Iridium satcom and GPS navigation updates take place when antennae on the tail periodically break the surface. Networks of gliders are showing promise in many kinds of naval missions.

Exploring their potential for ocean monitoring was the focus of Nato experiment REP14-MED conducted from 06 to 26 June in the Sardinian Sea and led by the Centre for Maritime Research and Experimentation (CMRE). Aboard research vessels Alliance (Nato) and Planet (WTD 71, Germany) and at research centres ashore, scientists and engineers from 21 partners and six nations have been testing new systems, technologies and solutions for ocean monitoring and seabed characterisation to improve Environmental Knowledge and Operational Effectiveness (ekoe) capabilities, says the organisation.

Gliders from Britain, Germany, France, the United States, the Centre and from many different manufacturers and institutions put to sea together to collect ocean physical data to improve the performance of ocean forecast models. Information from the gliders is expected to help diagnose and predict physical properties of the waters west of Sardinia, develop and test efficient sampling strategies, develop and test new methods to characterise the seabed, record underwater ambient noise and test recent developments in underwater observation techniques.

The Centre for Maritime Research and Experimentation operated its gliders from its control room in La Spezia, including hybrid types able to switch from buoyancy-driven propulsion to less efficient, but faster, propeller locomotion to transit between patrol areas.

Consortium partners include the Area Marina Protetta Penisola del Sinis and the Istituto per l'Ambiente Marino Costiero del CNR, both active in the local area. Their collaboration is intended to increase levels of automation in and improve the effectiveness of coordinated geographical, meteorological and oceanographic support for Nato operations.

Among the participating glider types was the SeaExplorer from French company ACSA ALCEN, a V-tailed design without wings or external moving parts, characteristics that reduce the risk of entanglement in debris or weed and of leaks. A relatively high ballast volume means that SeaExplorer travels at one knot, twice as fast as typical comparable gliders according to the company. Rechargeable lithium batteries provide two months endurance and typically 1,200 km range on a single charge.

NATO FURTHERS INTEGRATION, CO-OPERATION AND FUSION

In parallel, the organisation brought new data fusion, maritime asset allocation and underwater communication capabilities to its participation in the NATO Coalition Warrior Interoperability eXploration, eXperimentation, eXamination, and eXercise (CWIX) from 02 to 19 June. Held in Bydgoszcz, Poland, the 2014 exercise brought together fifteen Nato Nations, four partner nations and twelve Nato commands and 175 "capability configurations" to conduct more than 3,000 interoperability tests, all of which could enhance the use of naval robotic systems and their integration with manned assets.

CMRE's contribution to the situational awareness enhancing Fusion as a Service (FaaS) idea is a tool that uses the Collaborative Multi-Sensor/Source Fusion and Tracking (Commsoft) concept. This rapidly merges data from new sensors and sources to provide more detailed, accurate and timely information to the command and control chain.

The asset allocation capability is a maritime decision support tool that processes meteorological and oceanographic data, and provides adaptive density maps of risks which could help decision-makers to forecast scenarios. During CWIX, Nato planned to test the capability virtually in the Indian Ocean on counter-piracy scenarios.

CMRE's sub-sea contribution was the UnderWater Networked Communication (UWNetCom) capability developed in the Co-operative Anti-Submarine Warfare programme to enable real-time communication and interoperability among underwater vehicles, manned and unmanned. In the exercise, two Ocean Explorers built and run by Florida Atlantic University and an active acoustic source were simulated as support platforms, gathering and passing on information on asset positions, underwater detections and tracks, and environmental data to the maritime situational awareness services.

The North Atlantic Treaty Organization has also been working to advance the state of the art in naval robotic co-operation through a programme known as Morph, a European Commission effort to test multi-vehicle coordination and formation manoeuvring based on echo location.

In sea trials that took place in July of 2013 off the coast of Toulon in southern France at the European Centre of Underwater Technologies, which is part of the French Institute for Exploitation of the Sea (Ifremer), the above-mentioned Centre for Maritime Research and Experimentation demonstrated software for combined data communication and ranging technique for underwater acoustic networks. Using frequencies selected to optimise range and signal-to-noise ratio, the system exploits the precise time tagging provided by acoustic modems and knowledge of local sound speed through the water to infer the acoustic packets' time of flight. This, says the Centre, permits underwater robots to work together, navigate in formation and share data, resulting in a well-organised flock of vehicles: an underwater system of multiple, heterogeneous marine robots that cooperate. The Morph programme is due to be completed in 2016.

MULTISTATIC ANTI-SUBMARINE WARFARE

The biennial Proud Manta series of major Nato anti-submarine warfare exercises has provided opportunities to test a range of ideas and the 2013 event saw the Centre for Maritime Research and Experimentation experiment with a multistatic concept using autonomous underwater and surface vehicles, an active sonobuoy, a submarine acting as a target and the NRV Alliance. A pair of autonomous underwater vehicles used towed passive sonar arrays to

Obviously developed by IAI with speed in mind and for very rapid intervention as suggested by its Fabio Buzzi Design Stab series speedboat platform, the Katana system suite, which includes autonomous navigation capability can be adapted to other hulls. (Albatross)

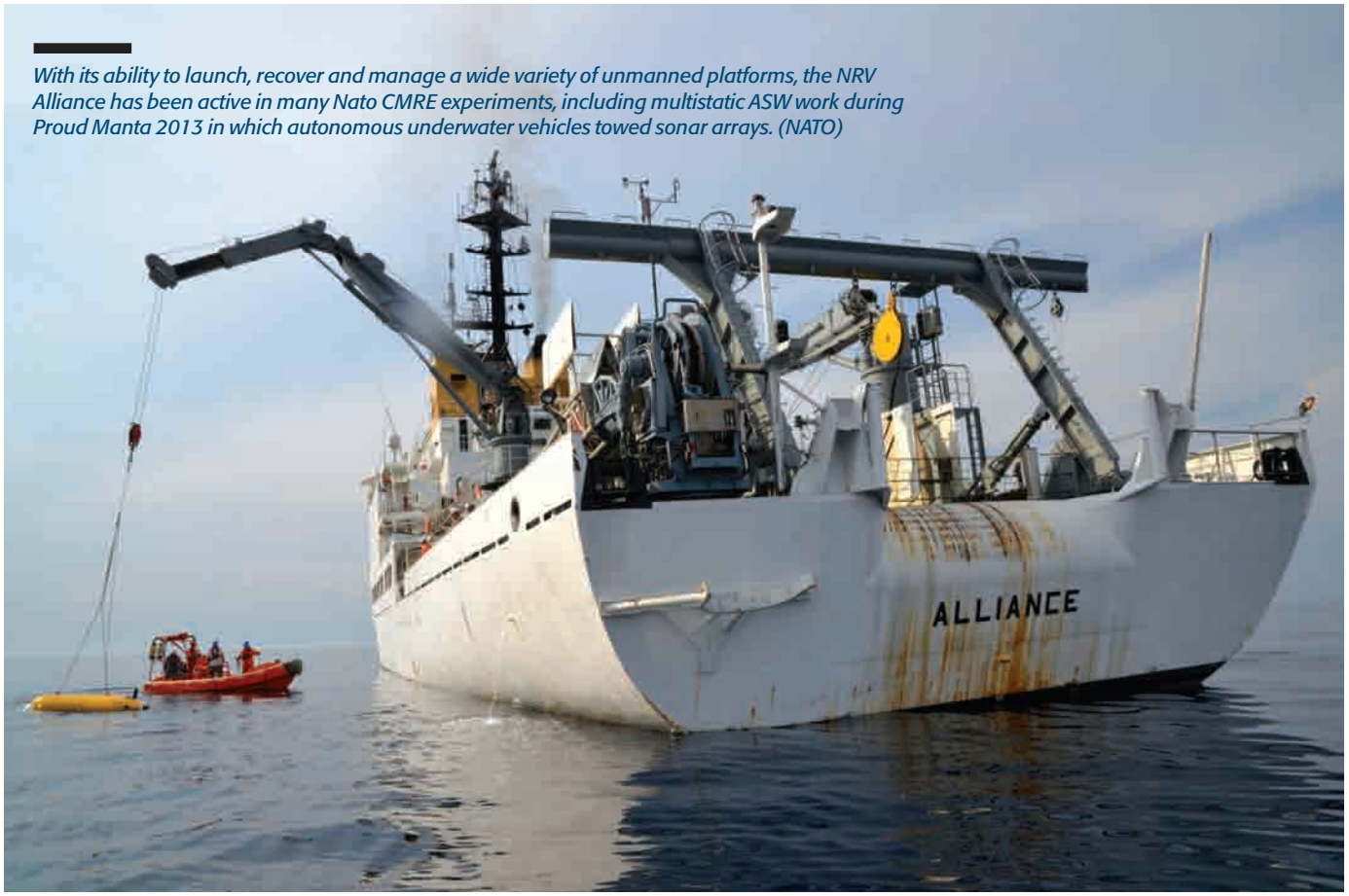
triangulate and locate anything target like that echoed transmissions from the active buoy. Embedded signal processing developed by the Centre enabled each vehicle to form a multistatic view of the battlespace, including their detections, which they communicated to the Alliance though a long-range, low-frequency acoustic modems for fusion on the ship's sonar displays. Also participating in the demonstration was a WaveGlider acting as a mobile gateway to re-transmit acoustic messages from the autonomous underwater vehicle via radio datalink to the Alliance.

Developed by Liquid Robotics, the WaveGlider is a very elegant vehicle that exploits wave motion to provide forward propulsion. The vehicle consists of a float connected by a long tether to a submerged unit with multiple wings, each of which pivots along its span-wise axis to produce a forward-thrust vector as the waves lift and drop the float. The tether is long enough to put the submerged unit below the bulk of the vertical wave motion, so that the tether lifts it through the water column when the float rises (if the tether were too short, the submerged unit would be inside the wave on which the surface unit is floating and would not generate thrust). The float module is fitted with solar panels to power sensors and radio equipment.

Buoyancy-driven gliders can remain at sea for months and Nateo is exploring their potential to improve environmental knowledge and operational effectiveness through long term ocean monitoring and seabed characterisation. ACSA ALCEN's Explorer took part in REP14-MED this summer. (ACSA ALCEN)

DARPA

Another focus for innovative ideas in naval robotics is, of course, the US Defence Advanced Research Projects Agency with programmes including the ASW Continuous Trail Unmanned Vessel (Actuv), Distributed Agile Submarine Hunting (Dash) and Upward Falling Payloads (UFP). The most recent of these to surface is the latter, the aims of the second phase of which were outlined on 26 March. The overarching purpose of the programme is to develop deployable, unmanned, non-lethal distributed systems that would lie on the deep-ocean floor in



With its ability to launch, recover and manage a wide variety of unmanned platforms, the NRV Alliance has been active in many Nato CMRE experiments, including multistatic ASW work during Proud Manta 2013 in which autonomous underwater vehicles towed sonar arrays. (NATO)

special containers for years, waiting for US forces to activate them remotely from distant command centres, recalling them to the surface when needed. This is a way of putting selected capabilities in position in preparation for distant crises in the face of the cost and complexity that limit the number of ships and weapon systems that the Navy can support in forward operating areas.

UPWARD FALLING PAYLOADS

The conceptual system would consist of a "payload", which executes waterborne or airborne missions after being deployed to the surface, a "riser" that provides encapsulation and launch, and the communications system that triggers the launch.

During Phase 1, the Darpa studied approaches to long-range communications, containment systems able to withstand deep ocean pressures, methods of launching payloads and likely missions for them.

"In this first phase, we really learned about how the pieces come together, and built a community of developers to think differently about unmanned distributed solutions for the maritime domain," said UFP programme manager Andy Coon. "The trick is to show how these systems offer lower-cost alternatives to traditional approaches, and that they scale well to large open-ocean areas."

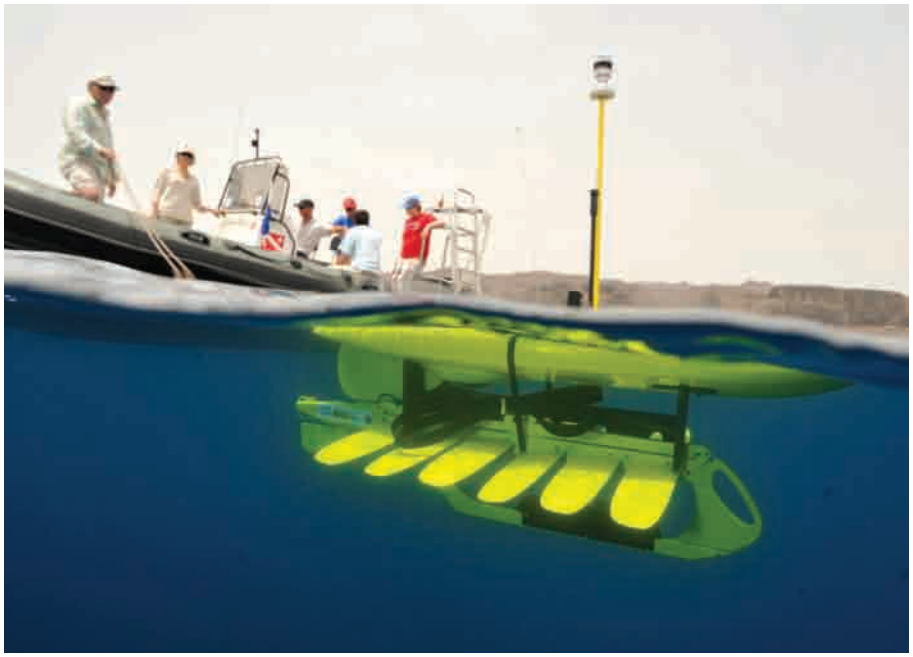
In Phase 2, the organisation intends to apply what is has learned to develop an demonstrate prototypes and is putting together teams experienced in deep ocean engineering and payload development. In particular, the Agency is looking for what it describes as technology communities that can team to provide expertise and innovation for small sensors, expendable and small unmanned systems, distributed communications and navigation technology, novel long-range underwater communications, and long-endurance mechanical and electrical systems that can survive for years in dormant states.

"As long as you can command the nodes remotely and quickly, and don't have to send a ship out to launch it, you're in good shape. Some Phase 1 approaches were more exotic than others, but we were pleased by the range of challenging options," said Andy Coon.

UFP funding for FY 14 is US $11.913 million with activity focused on system trade studies leading to conceptual designs, analysis to characterise long-range, deep-sea communications and development of conceptual designs for containment and launch systems. Funds increase in the FY 15 estimates to $18.964 million, and plans centre on developing a payload and a riser and demonstrating them along with a surrogate communication system to initiate a deployment from an intermediate depth. Development of communication subsystems is also set to begin in FY 15.

DISTRIBUTED AND AGILE

Still in deep water, the Dash programme seeks to couple deployed sonar nodes with long-endurance autonomous vehicles to detect, track and trail hostile submarines. From their very quiet deep ocean point, the sonar nodes would have a large field of view in which to detect submarines passing overhead. The defence research agency equates these sonar nodes to submerged satellites and calls them "subtulites", arguing that their significant field of view and the low-noise phenomena at extreme depths will permit a scalable number of collaborative sensor platforms to detect and track



Uninhabited seagoing robots are in contact with the air and underwater domains, making them ideal gateways between the two. Pictured is a Wave Glider from Liquid Robotics, a long-endurance, wave-driven vehicle that has participated in Nato antisubmarine warfare experiments as a communications node. (Liquid Robotics)

submarines over large areas. The Dash also addresses shallow water areas with distributed sensors, but exploits "non-acoustic" sensing from above.

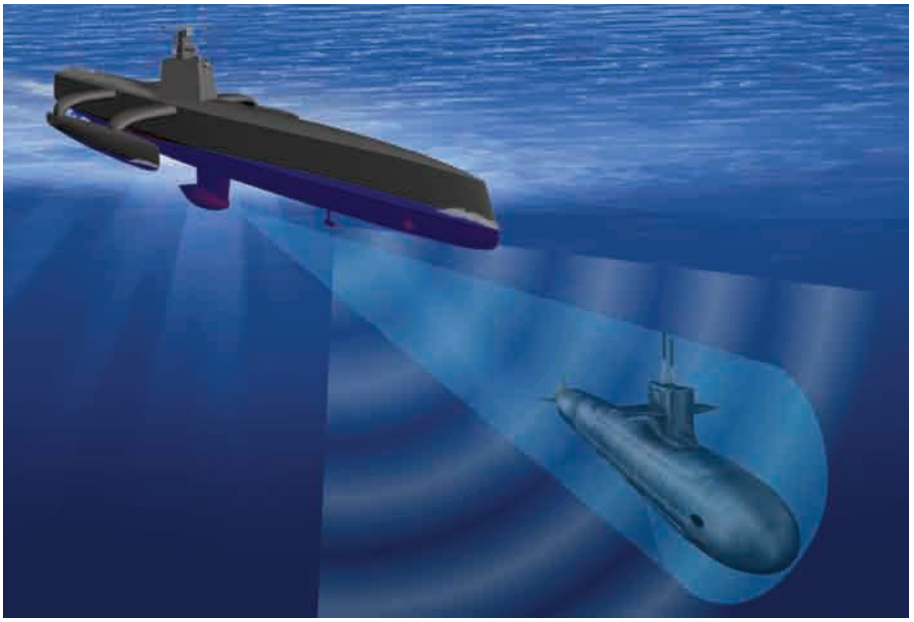
The programme has so far developed two prototype systems: the fixed passive sonar node, (which the Agency terms the Traps (Transformational Reliable Acoustic Path System), and the Shark (Submarine Hold At RisK) uninhabited underwater vehicle, with the latter intended to be an active sonar platform to track submarines after initial detection by the Traps.

Successful tests of both prototypes were announced in April of 2013. Developed by an SAIC-led team, the small, energy frugal and expendable Traps node sent data to a stationary surface node via acoustic modems, with further secure reach back to the SAIC's facilities via satellite. The Shark is under development by a team lead by Applied Physical Sciences and is based on a Bluefin Robotics Bluefin 21 vehicle, which completed its first tests at depth in February 2013. As of April 2013, the two were due to be tested together, with subsequent work likely to involve multiple sonar nodes and integration of an active sonar into the Shark.

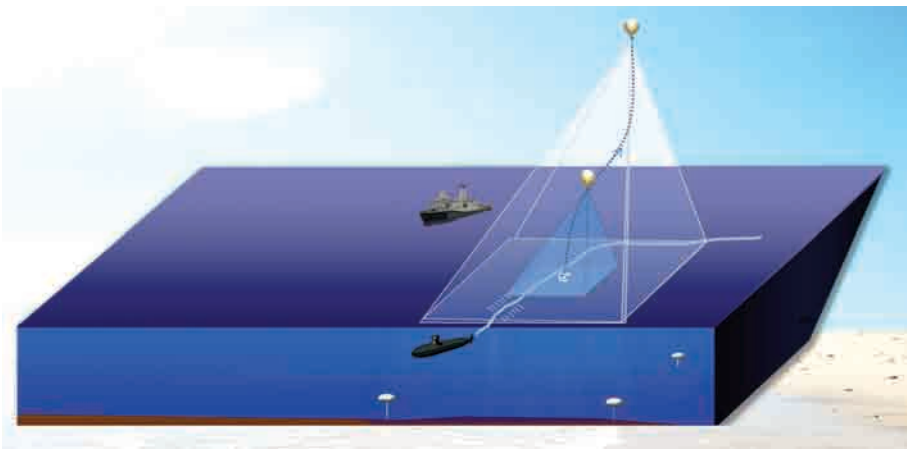
While no further announcements on the Dash programme have come from the Darpa, the programme remains in the FY 2014 budget with US $28.943 million allocated and in the FY 15 budget estimates at the considerably reduced level of $8.474 million and is slated for transition to the Navy. Headline achievements during FY 13 included demonstration of passive and active sonar prototypes scalable to large deep-ocean areas for wide area surveillance and manoeuvre warfare. The system showed the ability of both types of sonar to detect American submarines and the "scalability" to detect the quietest of threat diesel electric submarines. Testing of the initial multi-node communications network for persistent connectivity "from sea floor to shore" also began during this period, as did planning for demonstration of multi-node systems. Finally, the team completed "discovery and assessment" of non-acoustic signatures.

Plans for FY 2014 include completing the development of the deep-sea sonar node prototypes and the distributed, multi-node communications system, demonstrating extended remote monitoring of a passive sonar barrier network at sea and demonstrating the uninhabited underwater vehicles-based active sonar's deep sea detection and tracking capabilities. The last goal for FY 14 is to integrate technologies for "autonomous, reliable and secure" transfer of energy and data to fixed and mobile undersea systems.

Looking ahead to FY 15, the Dash programme plans include extending the endurance of the active and passive sonar nodes and demonstrating this capability at sea against a target, demonstrating connectivity from the sea floor to a remote shore station and integrating the distributed communications system with US Navy data transfer and C4I systems.



The Darpa ASW Continuous Track and Trail Unmanned Vessel (Actuv) effort seeks to develop a robot that can track and trail quiet conventional submarines for long periods, after rapid transit to the target area and acquisition of a quarry detected by a third party. (Darpa)



In Darpas's Upward Falling Payloads (UFP) concept, unmanned vehicles would be stored on the deep seabed in special containers for years before being called into action to perform waterborne or airborne missions; payload, "riser" and communications are key elements. (Darpa)

ACTUV – THE UNINHABITED SUB CHASER

The Actuv (ASW Continuous Trail Unmanned Vessel) programme is an effort to develop an uninhabited sub chaser that can sprint from a port or patrol area to reacquire and trail a hostile submarine detected by other means. Its first goal is to build and demonstrate an experimental platform with beyond state-of-the-art performance and designed from the outset for uninhabited operation. The second is to show that operating autonomous underwater vehicles at theatre or global ranges, from forward operating bases and using a sparse supervisory control model is feasible. The third and final top level goal is to use the Actuv's unique characteristics to evolve a game changing anti-submarine warfare capability for the US Navy.

Because nobody is intended ever to step aboard an Actuv at any point in its operating cycle, designers are not constrained by habitability considerations and can concentrate on achieving what the Agency terms disproportionate speed, endurance and payload fraction. Actuvs must have sufficient situational intelligence means to comply with the rules of the road and maritime law to enable them to navigate safely through operational deployments lasting months and covering thousands of miles. With innovative sensor technologies, it is designed to provide a low-cost system offering a fundamentally different risk calculus and one that can detect and track even the quietest submarine threats. Key technical areas include vessel design methodologies, ship system reliability, high-fidelity sensor fusion, novel application of sensors for anti-submarine warfare tracking, and holistic system integration.

Detailed design and the critical design review were completed, critical enabling technologies were demonstrated and an integrated system demonstration with surrogate Actuv hardware in the loop was carried out during FY 13. The key activities for FY 14 are sensor testing on a surrogate platform, starting construction of the prototype vessel and integration of mission hardware and software into the platform. Completion and testing at sea to validate the performance of the vessel, its sensor system and autonomous capabilities are scheduled for FY 15. Budget allocations for FY 13 and 14 were US $37.4 million and $20.831 million respectively, with the estimate for FY 15 at $11.865 million.

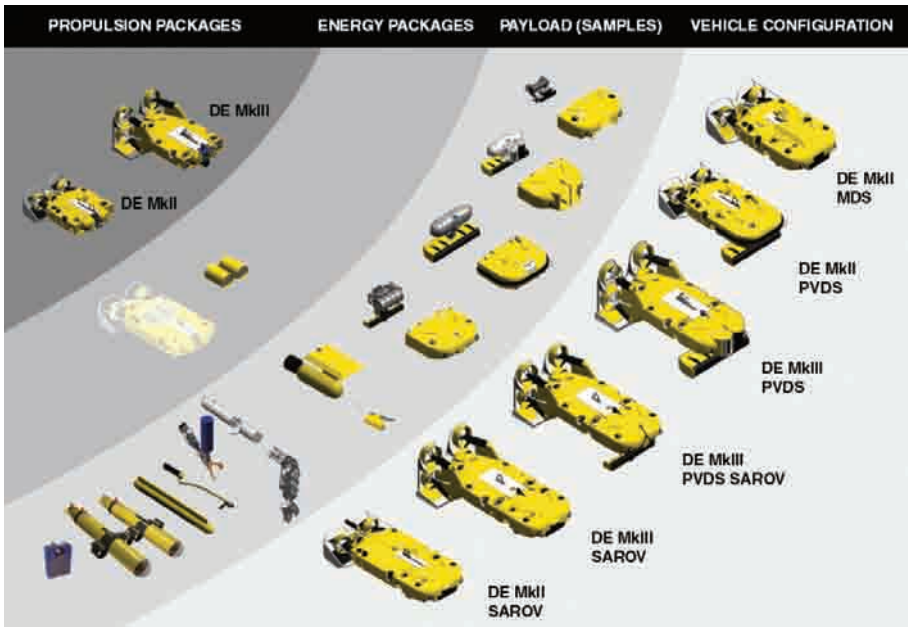
EXPERTISE FROM THE NORTH

With the exposed position of its Baltic coasts to incursions from the Soviet navy's submarines and the necessity to keep the Oresund strait under narrow surveillance and cleared of mines at all times during the Cold War, Sweden has developed a strong expertise in shallow water sonars and detectors.

To cut a long story short, and drawing on experience gained from computer controlled unstable configurations, notably with the Gripen, Saab embarked on the development of unstable underwater robots. One of the underwater vehicles to have pioneered the concept was the Double Eagle. Through its two main shrouded rear propellers and six secondary thrusters, this remote controlled system (see illustration herewith) has the ability to move in the three axes with diabolical precision which enables, for example, its telescopic arm to deposit with extreme accuracy a detonating charge near a mine.

The Double Eagle can carry all manner of sensors, and more particularly scanning sonars. The Double Eagle is agnostic in this

The Shark (Submarine Hold At Risk) is part of the Darpa's Distributed Agile Submarine Hunting (Dash) programme that aims to team a long-endurance underwater robots with a deep- sea sensor network known as the Transformational Reliable Acoustic Path System, Traps. (DARPA)



This chart illustrates the innumerable configurations that can be had with the Double Eagles in MkII and MkIII forms. (Saab)

respect, and the French Navy's units for example carry a Thales TSM 2022. The Mk II and more powerful MkIII (with four large aft propellers) iterations of the Double Eagle can be untethered and run autonomously and return home, in which case they are known as the Double Eagle Sarov – a name that has little to do with the eponymous Russian city, but much more with Saab Autonomous Remotely Operated Vehicle.

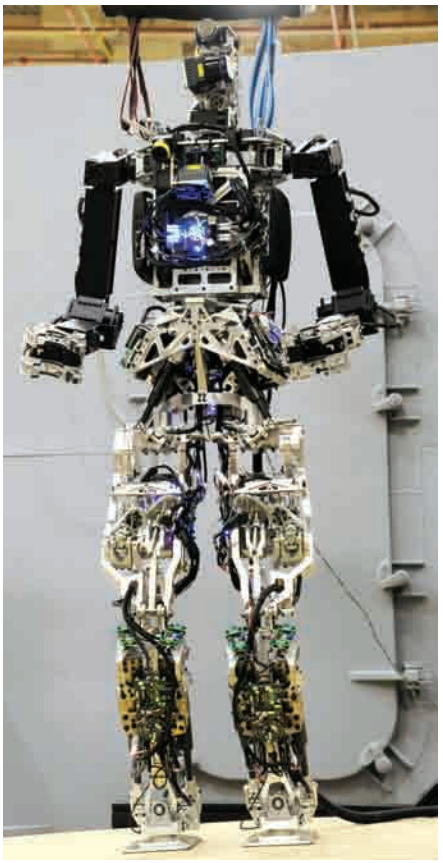
One of the fortes of the Double Eagles in mine-sweeping operations is their ability to swim ahead of their mothership, preventing the latter to sail into trouble's way. In addition, should push become shove in a perilous mine disposal mission, the robot has the ability to itself launch a swimming charge, a twin-propelled device by the name of Mine Sniper.

INSPIRATION FROM NATURE

As in other areas of robotics and engineering generally, taking ideas from nature is increasingly important for machines intended to work at sea. There are many examples of robots that mimic marine animals, but two that stand out are Boston Dynamics' BioSwimmer, which looks and moves like a tuna, and jellyfish-inspired vehicles that are the subject of research and development R&D at Virginia Tech. Tuna are famously fast – the yellowfin tuna can reach about 75 Km/hour – accelerate rapidly and swim efficiently over a wide range of speeds. Importantly for an autonomous tuna mimic, the front of the body remains stable despite the side-to-side beating of the tail, making life easier for any sensors. Jellyfish, on the other hand, are very slow but extremely energy efficient as they propel themselves with pulsations of their bell-like bodies.

One of the most ambitious bio-inspired creations, however, is intended to operate aboard ship to take on the dangerous role of putting out fires. The Saffir (Shipboard Autonomous Fire Fighting Robot) is an Office of Naval Research project to develop a humanoid robot "capable of finding and suppressing shipboard fires and working seamlessly with human fire fighters". With their hatches, coamings, ladders and corridors, warships are designed to allow humans to move around them and present major problems to machines that roll on wheels or tracks and that cannot hold on to railings, so a robot with a human-like physique ought to have some inherent advantages.

Boston Engineering's tuna-shaped BioSwimmer is one of many nature-inspired robots emerging from academic research and development that seeks leverage from aeons of evolution to create efficient vehicles - a successful tuna mimic could be both fast and stable. (Boston Engineering Corporation)



The US Navy's experimental Shipboard Autonomous Firefighting Robot, the Saffir, is designed to find and suppress shipboard fires, working seamlessly with human fire fighters, its human-like physique an advantage in an environment full of ladders, hatches and coamings. (US Naval Research Laboratory)

A candidate for the Navy's Damage Control Technologies for the 21st Century (DC-21) programme, the Saffir is designed to be able to walk in any direction, keep its balance in high sea states, negotiate obstacles, manipulate fire fighting equipment, use existing thermal shielding equipment and find its way around the ship by itself with the aid of a suite of sensors. The ability to respond to gestures and commands will help it to work with its human counterparts.

Robotics has established itself in several niches at sea and is expanding into new ones at a rate limited largely by budget and imagination.

STATE OF THE ART

What follows is an overview of current capabilities offered by industry around the world, and they are listed in manufacturer alphanumerical order.

5G Marine

Eclipse

Length: 11 m
Speed: 40 to 50 kt depending on propulsion system
Payload: Sensor suite options include high-resolution radar, EO turret with thermal and day TV cameras, Bosch day/night active IR marine camera, through-hull sensors, loud hailer

Propulsion: 2 x 550 hp Fiat N67500 diesel engines driving Rolls Royce Kamewa water jets, 2 x 13 kW electric motors for low speed operations
Notes: Eclipse produced by 5G International of North Palm Beach, Florida and boat builder Al Seer Marine of Abu Dhabi.

Bravo

Length: 36 ft (11 m)
Speed: 40 to 50 kt (74 to 93 kph) depending on powerplant

Notes: An autonomous RHIB that can be operated manned or unmanned, with the insertion/extraction role in mind, aimed primarily at special forces applications.

Sea Serpent

Length: 9.84 or 13.1 ft (3 or 4 m)
Notes: High speed unmanned RHIB built by a partnership between Al Seer Marine and 5G International. The Sea Serpent is designed for surveillance and security missions in near coastal areas and can be carried by larger craft.

AAI Corporation

Fleet Class Common Unmanned Surface Vessel

Weight: 7.7 tonnes
Length: 39 ft (11.88 m)
Speed: 28 kt (52 kph)
Endurance: 48 hours
Range: 1,200 nm (2,222 km) cruise
Payload: Bay measures 14 x 6 x 3.5 ft (4.26 x 1.83 x 1.067 m)

Notes: With a tow capacity of 5,000 lb (2,268 kg) at 10 kt (18.52 kph), CUSV pulls an L-3 Klein 5000 side scan sonar for mine detection and deploys an Atlas SeaFox UUV for mine destruction in US Navy Service. AAI Textron, General Dynamics Robotic Systems and Maritime Applied Physics Corporation cooperatively designed it for ASW, ISR and ASuW missions, plus launch and recovery of UAVs and UUVs.

ACSA

Basil

Weight: 350 kg
Length: 3.4 m
Speed: 3.5 kt
Endurance: 8 hours
Payload: 170 kg
Propulsion: electric
Notes: Described as a self-propelled buoy and a remotely controlled platform for sensor deployment, the Basil is a small USV that can navigate and station keep in sea states up to 3. Up to eight BASILs can be controlled together via ACSA's FleetManager software, allowing multiple simultaneous measurements.

SeaExplorer

Weight: 59 kg in air
Length: 2 m + 0.7 m foldable antenna
Speed: 1 kt max
Endurance: 2 months on one battery charge
Payload: 8 kg (3 kg wet payload, 5 kg dry payload and electronics)
Propulsion: Buoyancy driven with electric pump and Li-ion battery
Notes: Wingless underwater glider offered for oceanography and science, environmental protection and monitoring, oil and gas and defence and security missions. Military tasks include rapid area assessment and creation of sound speed profiles conductivity, temperature and depth measurements.

Aeronautics Defense Systems

Seastar

Weight: 6,000 kg
Length: 11 m
Speed: 45 kt cruise
Range/endurance: 300 nm + 10 hours on station

Payload: 2,500 kg for sensors including EO/IR cameras, radar, electronic warfare, PA system, non-lethal weapons and stabilised gun with fire control
Propulsion: 2 x 470 hp marine diesels with water jet propulsion
Notes: Large, fast vehicle marketed for protection of harbours, strategic facilities, offshore infrastructure, coastline patrol, ISR missions, target designation, jamming and decoy and force protection tasks.

Aselsan

Levent
Speed: 30 kt
Endurance: 4 hours minimum without running diesel engine
Payload: Mission specific options including weapons
Propulsion: Diesel engine

Notes: Optionally manned RHIB that can be tele-operated or autonomous. Offered for port and shipping security, ISR, coastal patrol, search and rescue and logistic support missions. Can also be used as a target vessel. Levent USV technology is designed for integration into standard boats.

Atlas Elektronik

SeaFox C
Weight: 40 kg in air
Length: 1.3 m
Speed: more than 5 kt
Diving depth: 300 m
Endurance/range: 1.2 km depending on

current and acoustic conditions
Payload: 1.5 kg shaped-charge warhead, relocation sonar, echo sounder, TV camera searchlights
Propulsion: Battery electric with four horizontal propellers and one vertical thruster
Notes: One-shot "wooden round" mine disposal vehicle in service with 10 navies that typically clears mines four times faster than methods using recoverable remotely operated vehicles, according to Atlas. Can be controlled from stand-alone console or integrated into existing MCMV displays.

SeaFox 1
Weight: Approx 40 kg in air
Length: 1.3 m
Speed: more than 5 kt
Diving depth: 300 m
Endurance/range: 1.2 km depending on

current and acoustic conditions
Payload: Relocation sonar, echo sounder, TV cameras, searchlights
Propulsion: Battery electric with four horizontal propellers and one vertical thruster
Notes: Recoverable, reusable inspection, training and mine identification version of SeaFox without warhead. Features rechargeable batteries, reusable communications cable, no expendable parts.

SeaFox Cobra
Weight: 43 kg
Length: 1.31 m
Speed: -0.5 to 6 kt
Diving depth: 300 m
Endurance/range: Up to 100 minutes

depending on mission profile
Payload: 8 kg, 600 x 480 x 230 mm Cobra ordnance disposal charge plus standard SeaFox sensors.
Propulsion: Battery electric with four horizontal propellers and one vertical thruster
Notes: Addition of detachable Cobra mine disposal tool enables reusable SeaFox to destroy multiple targets at low cost, particularly historical ordnance. RF coded initiation capability at up to 22 km for military version, 1.5 km for commercial variant.

SeaCat
Weight: Approx 160 kg
Length: Approx 2.4 m depending on payload
Speed: 3 to 4 kt typical, 6 kt max
Endurance: 6 10 10 hours

Payload: EdgeTech 2200 side scan sonar and Tritech Micron DST sector scanning sonar or micro-modem/transponder as standard. Interchangeable options include: Tritech Gemini imaging sonar, EdgeTech sub-bottom profiler, pan-tilt camera head, custom head with dedicated sensors (sampler, flourometer etc.), Blueview multi-beam sonar, MBES R2Sonic 2022 Notes: Fully autonomous survey UUV designed for quick mobilization and easy set-up to allow the operator to focus on the survey plan. Data is directly exportable (time-stamped and geo-referenced) to any major processing package.

SeaOtter Mk II
Weight: Less than 1,000 kg
Length: 3.65 m
Speed: 7 kt
Endurance: 20 hours
Payload: 160 kg
Propulsion: Battery electric with stern and vertical thrusters.
Notes: Multi-purpose AUV for civil and military operations. Features include twin-

hull "flat fish" design, modularity applied to structure, propulsion, energy, communication, navigation and payload. Missions include: MCM, covert ISR, rapid environmental assessment, sea bed mapping, hydrographic survey

Autonomous Surface Vehicles Ltd

C-Target 3

Weight: 325 kg
Length: 3.5 m
Speed: 20 kt + (25 kt + optional)
Payload: Wide range of optional visual, radar & thermal enhancements
Propulsion: 30 hp outboard two-stroke or four-stroke petrol engine, inboard diesel available

Notes: Lightweight, swarm capable, highly manoeuvrable fast marine target boat for naval gunnery training, weapons testing and ship command and control assessments. Features a repairable foam-filled aluminium hull, ballistic protection for engine and electronics.

C-Target 6

Weight: 1,200 kg
Length: 6.5 m
Speed: 35 kt +
Payload: Wide range of optional visual, radar & thermal enhancements

Propulsion: 125 hp outboard 2/4 stroke petrol
Notes: C-Target 6 is a powerful fast marine target boat designed for offshore use in up to sea state 4 either as a direct fire target or as a tow boat for inflatable targets. Swarm capable, it can be customised to resemble specific craft or configured as a USV. Features a rugged, repairable aluminium hull. Can be fitted with a console for manned missions.

C-Target 9

Weight: 2,750 kg (unmanned)
Length: 9.6 m
Speed: 50 kt +
Payload: Can be equipped with a wide range of radar, visual and thermal enhancements.
Propulsion: 2 x 300 hp Mercury Verado or 255 hp Mercury Optimax outboard motors, diesel power optional. Engines recessed with ballistic protection.

Notes: High-speed, adaptable, survivable, repairable, swarm-capable target boat for naval gunnery training, weapons testing and ship command and control assessments. Can tow targets and other small craft. Can be operated manned.

C-Target 13

Weight: 4,200 kg unmanned
Length: 12.9 m
Speed: 45 kt +
Payload: can be equipped with a wide range of radar, visual and thermal enhancements
Propulsion: 2 x 350 hp Mercury Verado outboard petrol engines (diesel option available).
Notes: High speed, highly realistic, swarm-capable target boat for use naval gunnery training, weapons testing and ship command and control assessments. Outboard engines are recessed into a protected area that along with the electronics enclosure can be fitted with ballistic protection panels. Can tow targets or other craft, manned operation optional.

C-Sweep

Weight: 9,000 kg unmanned
Length: 10.8 m
Speed: 25 kt + (no tow)
Endurance/range: more than 200 nm

Payload: Up to 20 kN towing force at 15 kt, options include side scan, multi-beam and diver detect sonar, clip-on mine sweep or winch deployed systems, electrical generator, daughter AUV launcher
Propulsion: 2 x 321 kW Yanmar 6LY3 marine diesels driving two 0.6 m diameter propellers
Notes: Rugged vehicle designed to offer a high degree of directional stability, substantial towing capacity for long-endurance mine sweeping missions and a robust electrical generating capacity to support mine sweeping equipment.

C-Stat

Weight: 450 kg
Length: 2.4 m
Speed: 3.7 kg
Endurance/range: Three sizes offer deployments of 4 days, 15 days and over 30 days at maximum of 250 nm
Payload: Integrated sensor payloads can be supplied configured by users
Propulsion: Diesel generator, battery and 2 X DC thruster in protected recesses
Notes: Offers a new capability in the reliable positioning of sensors at sea for extended durations without need of a ship on station or sea bed anchoring. Applications include surface to subsurface comms, port, harbour and ship security, oceanographic data collection.

C-Hunter

Weight: 2,000 kg Length: 6.3 m Speed: 8 kt max Endurance: 50 hours + at 6 kt
Payload: multi-beam, side scan sonar. CTD, sub-bottom profiler, PTZ camera, inspection ROV.
Propulsion: 1 x 30 hp Yanmar 3YM30 diesel engine

Notes: Long endurance work class semi-submersible USV designed for a wide range of commercial and military applications including hydrographic survey, MCM, ASW, AUV/ROV/towfish positioning. Command and control software enables single- and multi-unit operations.

BAE Systems

Archerfish

Payload: Target relocation sonar, camera lights, directed energy (shaped-charge) warhead

Propulsion: twin electric propulsors allow operation in transit mode from launch platform to target and hover mode during target identification and destruction.
Notes: Single-shot mine disposal system launched and operated from surface ships, helicopters and unmanned underwater vehicles. BAE Systems claims a factor of four reduction in mine clearance time.

Talisman M

Weight: 1,000 kg
Length: 4.5 m
Diving depth: 300 m
Payload: 500 kg
Propulsion: Electric

Notes: With a resemblance to a carbon fibre turtle, Talisman M has remote and autonomous operation capability, integrating remote control with the platform's combat system and mission payloads, combining the detection, classification and neutralisation MCM phases into a single solution.

Talisman L

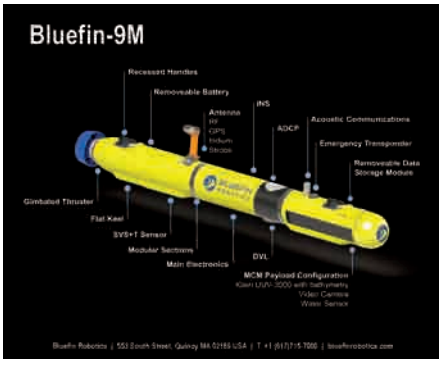
Weight: 50 kg
Length: 1.4 m
Speed: 5 kt max
Diving depth: 1 m to 300 m
Propulsion: Electric with four vectoring thrusters

Notes: Two-person portable littoral UUV designed to be operable from the much larger Talisman M UUV thanks to common navigation and C^3 systems.

Bluefin Robotics

Bluefin-9

Weight: 60.5 kg (dry)
Length: 1.75 m
Speed: 5 kt max



Endurance: 12 hours at 3 kt with standard payload
Diving depth: 200 m
Payload: Standard payload includes: Marine Sonic Technology 900/1800 kHz dual-frequency side scan sonar, Deep Sea Power and Light MultiSeaCam 1060, YSI 6560 CT probe, YSI 6136D turbidity probe
Propulsion: 1.5 kWh lithium polymer battery, gimbaled ducted thruster
Notes: Lightweight, two-man-portable autonomous underwater vehicle with a claimed mission turnaround time of less than 15 minutes. Intended missions include inshore survey, environmental monitoring and protection, MCM/UXO, port and harbour security, rapid environmental assessment, ISR.

Bluefin-12D

Weight: 260 kg (dry)
Length: 4.32 m
Speed: 5 kt max
Endurance: 30 hours at 3 kt with standard payload
Diving depth: 1,500 m
Payload: EdgeTech 2200-MP 120/410 kHz side scan sonar or Digital camera and LED-based strobe are standard payloads, others available

Propulsion: 5 x 1.5 kWh pressure-tolerant lithium polymer battery packs driving gimbaled, ducted thruster
Notes: Modular AUV with swappable payloads and battery modules for in-field mission reconfiguration. Applications include: MCM, UXO disposal, offshore survey, search and salvage, environmental monitoring and protection, archaeology and exploration/

Bluefin-12S

Weight: 213 kg
Length: 3.77 m
Speed: Up to 5 kt
Endurance: 26 hours at 3 kt with side scan sonar

Diving depth: 200 m
Payload: payload section includes interface specification for customer-integration of payload. Standard payloads include side scan sonar, synthetic aperture sonar etc.
Propulsion: 3 x 1.5 kWh lithium polymer battery packs, gimballed ducted thruster
Notes: Highly modular autonomous underwater vehicle with the ability to carry multiple payloads simultaneously. Can accommodate new payloads and enhanced energy sections. Applications include: MCM and UXO disposal, inshore survey, search and salvage, oceanography, scientific research.

Bluefin 21

Weight: 750 kg (dry)
Length: 4.93 m
Speed: Up to 4.5 kt
Endurance: 25 hours at 3 kt with standard payload
Diving depth: 4,500 m
Payload: EdgeTech 2200-M 120/410 kHz side scan sonar (option: EdgeTech 230/850

kHz dynamically focused), EdgeTech DW-216 sub-bottom profiler, Reson 7125 400 kHz multi-beam echo sounder are standard payloads, others are available
Propulsion: 9 x 1.5 kWh lithium polymer battery packs, gimballed ducted thruster
Notes: Highly modular autonomous underwater vehicle able to carry multiple sensors and payloads at once. Small size, A-frame or docking head launch and recovery allow it to take advantage of ships of opportunity. Missions include MCM, UXO disposal, offshore survey, search and salvage, oceanography, archaeology and exploration.

HAUV

Weight: 79 kg dry
Length: 1.07 m
Speed: up to 0.5 kt (1.5 kt optional)
Endurance: up to 3 hours with standard payload in zero current
Payload: Sound Metrics 1.8 MHz imaging sonar as standard

Propulsion: 1 x 1.5 kWh lithium polymer battery pack, 5 propulsion/control thrusters
Notes: Portable hovering AUV for tasks including ship hull and infrastructure inspection, port and harbour security, MCM and UXO disposal, scientific research.

Proteus

Weight: 2,182 kg
Length: 6.614 m
Notes: Large dual mode undersea vehicle concept, capable of operation in either manned or autonomous modes. Proteus will incorporate Bluefin's autonomy

technology for use in unmanned missions, and Bluefin's mission planning capabilities and power solution. The Columbia Group is developing the hull mechanical and electrical systems, Battelle battery charging and systems integration support.

Spray Glider

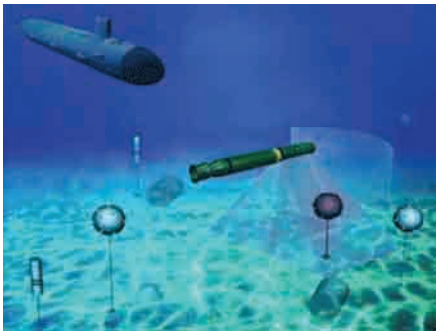
Weight: 52 kg (dry)
Length: 2.13 m
Speed: 19 to 35 cm/sec variable
Endurance/range: up to six months/4,800 km with standard payload
Diving depth: 1,500 m

Payload: Sea-Bird conductivity-temperature-depth (CTD), dissolved oxygen (optional), fluorometer (optional), turbidity/OBS (optional), altimeter (optional)
Propulsion: 17.5 MJ of energy in lithium primary batteries, buoyancy change pump
Notes: Spray collects water column data profiles using a pumped, conductivity, temperature and depth (CTD) sensor and other instruments. Applications include oceanography, environmental protection and monitoring, scientific research.

Boeing

AN/BLQ-11

Weight: 1,244 kg
Length: 6 m
Endurance: 60 hours (nominal load)
Diving depth: 1,000 m
Payload: Minehunting sonar and other sensors



Notes: AN/BLQ-11 is the US Navy's 21-inch (53 cm) diameter Long-term Mine Reconnaissance System (LMRS) that can be launched from and recovered into a submarine's torpedo tube. It is designed to

be launched, torpedo-style, from Los Angeles class submarines to survey, detect and gather data for more than 12 hours.

Echo Ranger

Weight: 5,308 kg Length: 5.5 m Speed: 8 kt max Endurance/range: 28 hours with normal load/80 miles submerged or up to 70 days "with the right power source" according to Boeing Diving depth: 3,050 m **Payload:** A wide variety of payloads have been installed, including acoustic and

radioactivity sensors, imaging sonars **Notes:** Built for the oil and gas industry in 2001, Echo Ranger remains in service as a research, development and scientific vehicle.

Boston Engineering Corporation

BIOSwimmer

Experimental tethered UUV that mimics fish swimming action, specifically a tuna,

for precise positioning and navigation in tight spaces in missions such as ship hull, pier and other submerged infrastructure inspection.

Central Mechanical Engineering Research Institute (CMRI) India

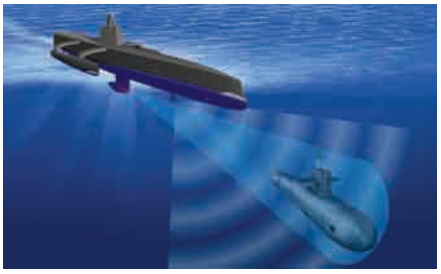
AUV-150

Weight: 490 kg
Length: 4.8 m
Speed: 4 kt max
Endurance: up to 6 hours
Diving depths: 150 m
Payload: conductivity, temperature and depth sensor and side scan sonar, navigation sensors include GPS, INS, DVL, altimeter
Propulsion: Lithium polymer battery, driving vectoring ducted thruster system
Notes: Work class AUV developed for seabed mapping, oceanography, MCM etc.

DARPA

ASW Continuous Trail Unmanned Vessel (ACTUV)

The ACTUV programme is intended to robustly track quiet diesel electric submarines. The programme is intended to explore the performance potential of a surface platform that a human is never intended board at any point in its operating cycle. The result is a design with reduced



constraints on conventional naval architecture elements such as layout, accessibility, crew support systems, and reserve buoyancy. The objective is to generate a vessel design that exceeds state-of-the art platform performance to provide propulsive overmatch against diesel electric submarines at a fraction of their size and cost.

Distributed Agile Submarine Hunting (DASH)

The DASH programme is intended to turn the tables on modern conventionally powered threat submarines through the development of advanced stand-off sensing from unmanned systems. Satellite-like "subtulite" sonar nodes will operate at significant depths in open ocean areas to detect submarines overhead, taking advantage of low noise at extreme depths. Distributed mobile sensors will exploit non-acoustic techniques from above on

continental shelves. They key prototype systems are the Transformational Reliable Acoustic Path System (TRAPS) fixed passive sonar node and the Submarine Hold at RisK (SHARK) UUV, an active sonar platform to track submarines after initial detections.

Hydra

Hydra aims to develop a distributed undersea network of unmanned payloads and platforms to complement manned vessels. The system would innovatively integrate existing and emerging

technologies to deliver various capabilities above, on and below the ocean's surface. By separating capabilities from the traditional platforms that deliver them, Hydra would serve as a force multiplier, enabling faster, scalable and more cost-effective deployment of assets wherever needed. Payloads include ISR and MCM. Each payload module would plug into a standardized enclosure that would securely transport, house and launch them, while sustaining functionality for weeks to months.

DGA/DCNS/Thales/ECA/DGA

Espadon

Weight: 25 tonnes
Length: 17 m
Payload: Towed sonar array, mine countermeasures systems including smaller UUV/AUV systems such as ECA's Alister family

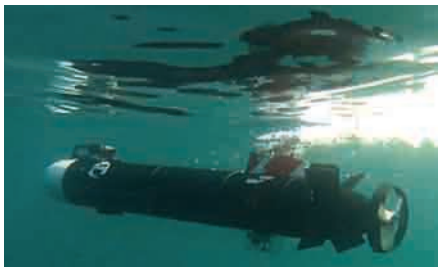
Notes: Optionally manned catamaran designed as a mother ship for a range of unmanned systems for mine

countermeasures. Developed by DCNS, ECA and Thales under contract to the DGA for the French Navy's System de Lutte Anti-Mines Futur (SLAMF) programme.

ECA Robotics

Alister 9

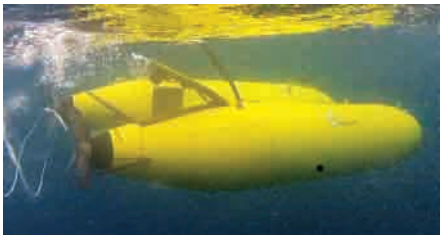
Weight: 50 to 90 kg in air depending on configuration
Length: 1.7 to 2.5 m depending on configuration
Speed: 2 to 3 kt
Endurance: 24 hours at normal speed



Diving depth: 100 to 200 m with greater depths optional
Payload: side scan, interferometric, obstacle avoidance sonars, multi-beam echo sounder, CTD probe, video camera and search lights
Notes: Portable AUV designed for confined area inspection, rapid area assessment, homeland security, MCM, seabed and hydrographic survey. Can be launched and recovered from RHIBs.

Alister 18 Twin

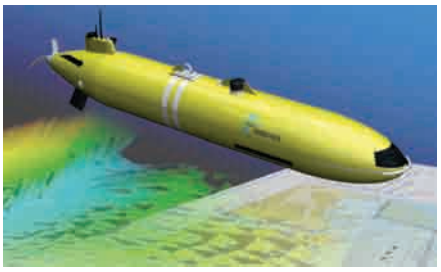
Weight: 490 to 620 kg in air
Length: 2.6 to 3.3 m depending on configuration
Speed: up to 5 kt
Endurance: 15 hours depending on



configuration and mission profile
Diving depth: 300 or 600 m, deeper on request
Payload: Obstacle avoidance and optional side scan, synthetic aperture or interferometric sonars, multi-beam echo sounder, CTD probe, acoustic camera, video camera and searchlights
Notes: Twin body AUV designed for harbour protection, mine identification, maritime structure inspection, hydrographic and littoral surveys. Inspection accuracy improved by stereoscopic cameras, hovering capability, manoeuvrability.

Alister 18

Weight: 290 to 440 kg depending on configuration
Length: 3.5 to 4.6 m depending on configuration
Speed: 3 kt



Endurance: 24 hours at nominal speed
Diving depth: 600 m standard, deeper on request
Payload: Side scan, synthetic aperture, interferometric and obstacle avoidance sonars, multi-beam echo sounder, CTD probe, video camera
Notes: AUV designed for homeland security, MCM, rapid environmental assessment, hydrographic survey missions and operation from non-dedicated ships.

Alister 27

Weight: 800 to 1,000 kg in air depending on configuration
Length: 5 m
Speed: 3 kt
Endurance: 30 hours at normal speed
Payload: side scan, synthetic aperture, interferometric and obstacle avoidance sonars, multi-beam echo sounder, sub-bottom profiler, CTD probe, cameras and lights

Notes: Large, multi-sensor AUV designed for a wide range of missions including MCM, covert ISR, rapid environmental assessment, homeland security, sediment analysis, seismic survey, hydrographic survey.

K-STER

Weight: 50 kg
Length: 1.5 m
Speed: more than 6 kt
Endurance/range: more than 1 km
Diving depth: 300 m (600 m + version optional)
Payload: Shaped charge insensitive explosive mounted in tiltable head for high attack accuracy, colour video camera, variable high frequency sonar, searchlight

Propulsion: Battery electric system with 2 horizontal and 2 vertical thrusters
Notes: One-shot mine killing ROV with automatic guidance designed for operation from non-dedicated platforms. Destroys moored, bottom, partly buried mines.

Sea Scan

Weight: 50 kg in air Length: 1.5 m Speed: 0 to 6 kt Endurance: 2 hours max Payload: Rotary payload carrier tilts through 180 deg, day night colour video camera, variable high intensity LED searchlights, high-resolution

imaging sonar (BlueView P900/130) or multi-beam profiling sonar (such as BlueView MB1350), chemical and turbidity sensors, magnetometer Propulsion: Battery electric with 2 horizontal and 2 vertical

thrusters Notes: Inspection ROV using K-STER related platform designed for fast, accurate inspection of the sea floor and immersed structures in salt and fresh water, stable in strong currents. Defence/security applications include hull and pier inspection for anti-smuggling/piracy missions.

Roving Bat

Weight: 135 kg in air
Length: 1.105 m
Speed: 2 kt in "flying" mode, 0-19 metres/minute in "crawling" mode
Endurance: Unlimited (externally powered via umbilical)

Diving depth: 100 m
Payload: Zoom colour TV camera under dome, wide-angle black and white TV camera, two 150 W lights
Propulsion: Remote electrical supply drives six thrusters and two tracks
Notes: Crawling and swimming ROV for inspection of ship hulls and submerged structures, can be configured with other sensors and effectors for detecting and neutralising suspicious devices.

Olister

Weight: 600 kg in air as standard including sonar or mine disposal charge Length: 3.1 m Speed: more than 6 kt depending on range, depth and configuration Endurance: unlimited in MIDS mode powered by ship through umbilical, up to 2 hours on batteries in FDS mode.
Payload: NATO disposal charge, manipulator, sonar, B&W or colour video camera

Propulsion: Umbilical and/or batteries powering 4 horizontal and 2 vertical thrusters
Notes: MCM ROV/AUV that performs Forward Detection Sonar (FDS) missions ahead of the ship including detection and classification of moored mines, seabed survey, and Mine Identification and Disposal System (MIDS) tasks including relocation, identification and destruction of ground and moored mines, mid-water or seabed inspection.

PAP Mk5

Weight: 890 kg in air with NATO charge
Length: 3.16 m
Endurance/range: unlimited powered by ship through umbilical/2,000 m max horizontal operating range

Diving depth: 300 m
Payload: Sonar or camera for detection and identification, 120 kg NATO mine destruction charge
Propulsion: Umbilical, electric motors, thrusters
Notes: ROV for identification and destruction of bottom-laid and tethered mines. More than 500 are in service with 20 navies, according to ECA.

Inspector Mk1

Weight: 2,100 kg fully loaded
Length: 7.1 m
Speed: up to 35 kt or 25 kt with towed secondary target
Endurance: more than 15 hours at 20 kt/ 10 nm under remote control
Payload: expendable towed target, 360

degree day/night video camera system, other electro-optical and CBRN sensors
Propulsion: 250 hp inboard turbodiesel, propeller
Notes: Target USV based on RHIB capable of remotely controlled and fully autonomous operation in sea states up to 3.

Inspector Mk2

Weight: up to 4,700 kg
Length: 8.4 m
Speed: 0-25 kt with station keeping ability
Endurance: 20 hours at 6 kt
Payload: Up to 1,000 kg, rotary bow arm can deploy a variety of sensors.

Propulsion: 2 x 170 kW or 215 kW diesels driving water jets
Notes: Imagery and bathymetric survey USV. Mission oriented sensors include a multi-beam echo sounder, sub-bottom profiler, side scan sonar, magnetometer. Data acquisition and post processing capabilities include sediment analysis, bathymetry, magnetic mapping and imagery.

Elbit Systems

Silver Marlin

Weight: up to 6,500 kg
Length: 10.67 m
Speed: 45 kt
Endurance/range: 24 hours/500 nm
Payload: 2,500 kg, COMPASS multi-sensor EO turret with CCD TV camera, mid-wave

thermal imager, laser aiming, range finding, designation and target illuminators, remote weapon station with 7.62 mm machine gun and fire control system.
Propulsion: 2 x 315 hp diesel engines driving propellers
Notes: USV designed for ISR, force protection, anti-terror, anti-surface warfare, MCM, SAR, EW, port and waterway patrol missions. Autonomy includes obstacle avoidance.

Stingray
Length: 3.2 m
Speed: 45 kt
Endurance: 8 hours
Payload: 250 kg

Propulsion: Piston engine driving water jet
Notes: Jet-ski-based USV offered for ISR, force protection/anti-terror, offshore infrastructure security, battle damage assessment and other littoral missions.

Gavia (Teledyne)

Gavia Defence
Weight: 49 kg in air for base vehicle, 62 kg in typical MCM configuration
Length: 1.8 m for base vehicle, 2.6 m in typical MCM configuration
Speed: more than 5.5 kt

Endurance: 6 to 7 hours at 3 kt with one battery module, 12 to 14 hours with two
Diving depth: 500 or 1,000 m
Payload: Options include swath bathymetry module, sub-bottom profiling module, sonar training module, custom payload modules for user supplied instrumentation
Propulsion: Electric motor powered by rechargeable, field swappable battery modules
Notes: Self-contained, man portable, modular platform capable of operating from vessels of opportunity or from the shore in MCM, ASW, sonar training, rapid environmental assessment. ISR, search and recovery missions.

Gaymarine

Plutino Miki
Weight: 55 to 90 kg depending on configuration
Speed: up to 6 kt depending on configuration
Endurance: unlimited, powered from ship via umbilical
Diving depth: 300 m

Payload: up to 15 kg: 3 sonars including high frequency identification sonar for target recognition in zero visibility, 2 TV cameras
Propulsion: 2 x horizontal and 1 x vertical electric motor
Notes: Low cost expendable or training ROV designed for easy handling, relatively high speed and payload capacity, fully compatible with Pluto ROV family consoles. Can be configured as an AUV.

Pluto
Weight: 160 kg in air
Speed: 4 kt depending on configuration
Endurance: unlimited, powered by ship via umbilical

Diving depth: 300 to 1,000 m
Payload: 45 kg including 1 sonar, 1 TV camera and 1 stills camera, spotlights
Propulsion: Electric motors powering 2 horizontal, 2 vertical, 1 lateral thrusters
Notes: Inspection and payload delivery ROV optimised for "extreme" manoeuvrability and positioning capabilities, full tilt capability for all sensors. Can be configured as an AUV.

Pluto Plus
Weight: 315 kg
Speed: 6 kt
Endurance: unlimited, powered by ship via umbilical ?
Diving depth: 300 m (others on request)
Payload: 100 kg in air, 3 sonars including high frequency sonar for target recognition in zero visibility, 1 TV camera, optional long-range sonar on request

Propulsion: 2 horizontal, 2 vertical and 1 lateral thrusters
Notes: Inspection and MCM ROV designed for "excellent" manoeuvrability and positioning, offers full pan and tilt on all sensors. Can be configured as an AUV.

Pluto Gigas
Weight: 600 kg in air
Speed: more than 7 kt
Endurance: unlimited, powered by ship via umbilical
Diving depth: 600 m (others on request)

Payload: 100 kg, 4 sonars, including high frequency target recognition sonar and integrated long-range sonar, and 1 TV camera, spotlight
Propulsion: 4 horizontal, 2 vertical and 2 lateral thrusters
Notes: ROV for use in extreme conditions, can operate from ships lacking specialised sonar, offers "excellent" manoeuvring and positioning, full pan and tilt for sensors. Can be configured as an AUV.

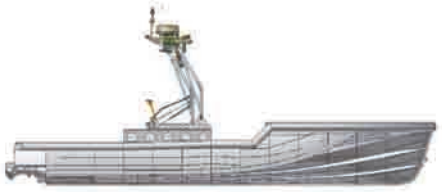
Bat
Weight: 650 kg
Speed: 0 to 18 kt
Diving depth: 300 m (others on request)
Payload: 100 kg in air, 3 sonars, TV camera, torpedo pinger finder
Propulsion: 4 horizontal, 2 vertical and 2 lateral thrusters

Notes: Reusable target for exercising sonars and torpedoes that can also serve in MCM and inspection roles. Speed realistic as conventional submarines typically operated at under 4 kt. Operator can change parameters in real time.

General Dynamics Robotic Systems

Draco

Weight: 7,700 kg without payload
Length: 12.2 m
Speed: 30 to 35 kt
Endurance: 24 to 48 hours



Payload: 2,276 kg, 726 kg tow at 20 kt goal, ASW sensor systems including dipping sonar, active source, towed array. Likely payloads include a torpedo launcher.
Propulsion: 2 x Yanmar 6LY3A-STP engines driving Rolls Royce Kamewa water jets
Notes: Anti-submarine warfare USV for Littoral Combat Ship. Designed specifically to address ASW mission needs, Draco possesses margin through careful design selections enabling it to meet the needs of many mine and surface warfare missions, says GDRS.

USV capabilities

GDRS is developing a wide range of USVs for the US Navy. Capabilities under development include: sensor-based situational awareness, dynamic route planning, harbour and sea navigation, docking, and evasive manoeuvres. They are

also to be capable of dynamic reconfiguration and management of systems and resources. Likely missions include: persistent ISR (radar, EO/IR, SIGINT, CBN), port & border security, special ops support, SAR, communications relay, maritime protection: anti-submarine, sea skimming missiles, small boat IED, track and trail, ice patrol.

Global Teknik

Globida

Weight: 300 kg
Length: 3.95 m
Speed: 30 kt
Endurance: 10 hours
Payload: Radar, sonar, day/night electro-optics
Propulsion: Gasoline engine driving water jet

Notes: Ship- or shore-launched USV capable of autonomous or manual control. Developed with Turkey's TUBITAK scientific and technological research council.

IAI

Katana

Length: 12 m
Speed: 60 kt
Endurance/range: 350 nm

Payload: payloads including electro-optical, communication systems, radio (line of sight or non line of sight), radar and weapon systems
Propulsion: 2 x 560 hp diesels
Notes: New optionally manned USV for homeland security missions and the protection of exclusive economic zones, including harbour security, patrol of shallow coastal and territorial waters, surface and electronic warfare and offshore platform protection.

iRobot

1KA Seaglider

Endurance: 7 to 9 months/3,800 km
Diving depth: 50 to 1,000 m
Payload: 4 kg, conductivity, temperature and depth measurement and other oceanographic sensors
Propulsion: Electrically driven hydraulic

buoyancy change pump
Notes: Very long endurance buoyancy driven glider for oceanographic, ISR and harbour defence applications.

International Submarine Engineering

Dolphin Mk 1

Weight: 2,832 kg
Length: 7.3 m
Speed: 12 kt continuous with 3 kt reserve for station keeping

Endurance: 26 hours at 12 kt
Payload: Minehunting sensors include the Klein 5500 single beam side scan sonar, the AN/AQS 14 side scan sonar and the Reson 8101 Seabat. Other sonar options include AQS 14, AQS 20, TSM 2054 and ISE Aurora
Propulsion: 1 x 150 hp Sabre turbocharged marine diesel, snorkel fed
Notes: Semi-submersible minehunting and hydrographic AUV developed from 1981 for Canadian Hydrographic Service and first ordered by the US Navy in 1985. Has logged more than 8000 hours in operation.

Dorado

Weight: 5,900 kg (fuelled)
Length: 8.23 m
Speed: 16 kt max without tow, 12 kt with tow
Endurance: 12 hours at 200m depth with tow, 28 hours without
Payload: 210 kg, options include ISE Aurora towfish, MB side scan sonar

Propulsion: 1 x 315 kW Caterpillar 3126 turbocharged snorkelling marine diesel
Notes: Semi-submersible minehunting vehicle in service with the Canadian Navy

Explorer

Weight: 640 to 1,850 kg
Length: 4.5 to 6.0 m
Speed: 0.5 to 2.5 m/sec
Endurance/range: 24 to 85 hours/120 to 450 km

Diving depth: Systems rated at 300, 1,000, 3,000, 5,000 and 6,000 m
Payload: CTD, side scan sonar, sub-bottom profiler, multi-beam echo sounder typical
Propulsion: 1.6 kWh lithium ion battery modules driving electric propulsor
Notes: Modular vehicle comprising of a forward free-flooding section, full diameter pressure hull and a free flooding aft section.

Arctic Explorer

Weight: 2,200 kg dry Length: 7.4 m Speed: 0.5 to 2.5 m/sec, 1.5 m/sec typical cruise Endurance/range: 80 hours/450 km Diving depth: 5,000 m Payload: Knudsen 118 kHz single-beam echo sounder, Seabird FastCat CTD, Kongsberg Simrad 200 kHz, EM2000 multi-beam echo sounder
Propulsion: Exide Technologies rechargeable lithium ion batteries
Notes: Arctic Explorer is a derivative of Explorer. ISE has built two Arctic Explorers for Natural Resources Canada to map the sea floor underneath the Arctic ice shelf in support of Canada's claim under Article 76 of the United Nations Convention on the Law of the Sea.

Trailblazer

Weight: 700 kg
Length: 2.5 m
Speed: 6 kt coaxial velocity
Endurance: Unlimited - powered from ship through 900 m umbilical

Payload: 4 x 22 kg mine disposal charges, sonar, camera systems
Propulsion: 25, 30 and 50 hp motors, thrusters
Notes: Lightweight, highly manoeuvrable ROV developed for MCM missions. Fits 6 m ISO container, launched and recovered by A frame or cranes. In service with Canadian Navy.

Kockums AB

Piraya

Weight: 400 kg full load displacement
Length: 4 m
Speed: more than 20 kt
Endurance/range: more than 60 nm

Payload: 100 kg, can include TV and IR cameras, radar, communication relays, CBRN sensors, loudspeakers, small arms
Propulsion: Outboard engine
Notes: Test and experimental USV platform for coastal patrol use by navies, police forces and coast guards. Group autonomy system intended to enable one operator to control a group of vehicles.

Kongsberg Maritime

Munin

Weight: less than 300 kg in air
Length: 3 or 4 m depending on configuration
Speed: 4.5 kt max
Endurance: 12 to 24 hours
Diving Depth: 1,500 m standard, 600 m optional

Payload: Tailored EM 2040 multi-beam echo sounder, EdgeTech side scan sonar, NBOS CT sensor, terrain following and collision avoidance sonar, EdgeTech sub-bottom profiler, optional still image camera
Propulsion: internal 5 kWh standard, exchangeable 5 kWh lithium ion battery modules
Notes: AUV capable of running several payload modules simultaneously including side scan sonar, multi-beam echo sounder, sub-bottom profiler and camera together.

Hugin

Weight: 1,200 to 1,900 kg in air
Length: 5.4 to 7 m depending on configuration
Speed: 2 to 6 kt
Endurance: 24 to 74 hours with all sensors operating
Diving depth: 1,000, 3,000 or 4,500 m

Payload: HISAS 1030 interferometric SAS, EM 2040 multi-beam echo sounder, EdgeTech side scan sonar, EdgeTech sub-bottom profiler, SAIV CTD sensor, stills camera, terrain following/collision avoidance sonar, chemical sniffers, turbidity sensor
Propulsion: lithium polymer battery, 1 or 2 exchangeable 24 kWh power packs
Notes: Large AUV designed for seabed mapping, pipeline inspection and mine reconnaissance, precise navigation and high resolution sensors emphasised.

Seaglider
Weight: 52 kg dry
Length: 1.8 to 2 m depending on configuration
Speed: 0.5 kt (25 cm/sec)
Endurance: up to 10 months depending on configuration, sampling rate and operational area
Payload: current profilers, CTD sensors, WET Labs backscatter/fluormeter, dissolved oxygen sensors, Photosynthetically Active Radiation (PAR) sensor
Propulsion: Lithium sulfuryl chloride primary batteries 24V and 10V packs, 17 MJ
Notes: Glider AUV developed for continuous long-term measurement of oceanographic parameters. Vehicle is controlled remotely via internet and satellite link.

Hydroid Remus 100
Weight: 37 kg in air
Length: 1.6 m
Speed: 5 kt max
Endurance: 22 hours at optimum speed of 3 kt

Diving depth: 100 m
Payload: acoustic Doppler current profiling, side scan sonar, CTD, bathymetry, sound speed, oxygen optode pH, oxygen reduction potential sensors
Propulsion: Direct dive DC brushless motor to open 3-bladed propeller
Notes: Lightweight AUV designed for coastal marine research, hydrographic, offshore/energy and defence applications including MCM, harbour security, environmental survey, search and salvage.

Hydroid Remus 600
Weight: 240 kg
Length: 3.25 m, varies with configuration
Speed: up to 4 kt
Endurance: 24 hours typical

Diving depth: 600 m, 1,500 m option
Payload: Standard sensors include acoustic Doppler current profiling, pressure, conductivity and temperature, depth. Options include dual frequency side scan sonar, synthetic aperture sonar, ECO sensors, video camera, acoustic imaging, video camera, electronic stills camera, single frequency side scan sonar, sub-bottom profiler.
Propulsion: direct drive DC brushless motor to open two bladed propeller
Notes: Naval missions include hydrographic survey, MCM, harbour security, search and salvage, debris field mapping.

Hydroid Remus 6000
Weight: 862 kg in air
Length: 3.84 m
Speed: up to 5 m
Endurance: 22 hours typical subject to speed and sensor configuration
Diving depth: 25 to 6,000 m (4,000 and 6,000 m versions available)
Payload: Standard sensors include acoustic Doppler current profiler, side scan sonar, CTD; options include dual frequency side scan sonar, flourometers, acoustic imaging, video camera, electronic still camera with

strobe light, sub-bottom profiler
Propulsion: 11 kWh Li-ion battery pack, direct drive DC motor, 2 bladed propeller
Notes: AUV designed for littoral to deep operations using same interface as Remus 100.

Liquid Robotics

Wave Glider SV2
Weight: 90 kg
Length: 2.1 m (float), 1.91 m (subsurface unit)
Speed: 0.5 to 1.6 kt
Endurance: designed to operate for years at sea with regular maintenance
Payload: 18 kg, basic payload includes water

speed sensor, AIS receiver, radar reflector, light and flag, 2 sensor modules in float
Propulsion: Mechanical conversion of wave energy into thrust, 665 Wh rechargeable Li-ion battery pack, 112 W solar array
Notes: Hybrid wave and solar-powered USV optimized for individual or small group deployments carrying preconfigured suites of sensors for specific science and security missions.

Wave Glider SV3
Weight: 122 kg
Length: 2.9 m (float), 1.9 m (subsurface unit)
Speed: 1.5 to 2.3 kt with auxiliary thruster, 1 to 2 kt without

Endurance: Operates for years with regular maintenance
Payload: 45 kg in float, basic sensors include water speed sensor, AIS receiver, Aimar 200WX weather station, wave data, radar reflector, light and flag. Adaptive Modular Power System is designed to accommodate power hungry payloads such as sonar.
Propulsion: conversion of wave energy into thrust, auxiliary electric thruster, 170 W solar array, up to 7.8 kWh of rechargeable Li-ion battery power
Notes: Wave and solar powered USV designed to travel tens of thousands of miles collecting real time data in demanding conditions.

Lockheed Martin

Marlin
Weight: 954 kg
Length: 3.05 m
Speed: 4 kt max

Endurance: 12 to 24 hours depending on mission
Diving depth: 300 m
Payload: 114 kg including 3D imaging sonar, HD video camera, forward looking sonar, multi-beam echo sounder, HID light, on board mission data recording
Propulsion: 2 horizontal and 2 vertical thrusters
Notes: Sub sea infrastructure inspection AUV with advanced sensors, software and navigation capability. Autonomy components include vehicle control, perception and response.

Remote Minehunting System

Weight: 5,828 kg
Length: 7.01 m
Speed: 16 kt transit, - to 12 kt search

Endurance/range: 24 hours/operates at long over-the-horizon ranges
Payload: Bow mounted SeaBat 6012 sonar, AN/AQS-20A towed variable depth minehunting sonar detects, classifies, localises and identifies bottom and moored mines in littoral regions
Propulsion: 1 x 370 hp Cummins 370B turbodiesel
Notes: Semi-submersible snorkelling Remote Minehunting System uses Remote Multi-Mission Vehicle and AN/AQS-20A sonar as the mainstay of mine reconnaissance capability in the Navy's Littoral Combat Ship MCM package.

Maritime Robotics AS

Mariner

Weight: 1,700 kg
Length: 5.6 m
Speed: more than 30 kt
Endurance: more than 50 hours at 5 kt
Payload: EO/IR camera, radar, CTD, ADCP, HPR systems, echo sounder (single or multi-beam), sonars typical
Propulsion: Volvo Penta D3 marine diesel, Hamilton 241 water jet, bow thruster
Notes: Multi-purpose USV with hull and

superstructure made of polyethylene and based on PolarCirkel work boat, "unsinkable" and almost maintenance free. Offers manual and automatic control, dynamic positioning, formation control.

Meggitt Training Systems

Barracuda

Weight: 2,074 kg Length: 7.24 m Speed: 36 kt in sea state 3 Endurance/range: 4 hours/180 nm at 36 kt, 10 hours/300nm at 20 kt Payload: 227 kg at 35 kt, 1,361 kg bollard pull at 17 kt, passive/active radar

augmentation, visual augmentation, scanning projectile impact evaluation system, automatic winch Propulsion: 1 x 225 hp Volvo D4 marine turbodiesel Notes: Barracuda Unmanned Surface Vehicle – Target is based on a modified, navy standard, glass fibre RHIB. Allows for remote control from distances greater than 10 nautical miles or can be configured for over-the-horizon control.

Hammerhead

Weight: 900 kg
Length: 5.2 m
Speed: 35 kt in sea state 3, faster in sea state 2
Endurance: 12 hours at 10 kt, 8 hours at 20 kt, 5 hours at 30 kt
Payload: passive/active radar augmentation, video TM, visual augmentation, Doppler radar miss distance indication
Propulsion: 135 hp MerCruiser 3.0l

gasoline engine with MerCruiser Alpha 1 drive
Notes: USV target with surface effect hull designed to mimic a fast inshore attack craft in swarms of up to 50 vehicles. Replicates high-speed naval tactics including crossing patterns, zigzags and other evasive manoeuvres.

M Ship

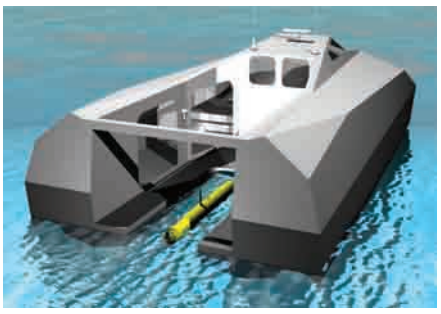
Stiletto MOC

Weight: 127 tonnes
Length: 26.82 m
Speed: up to 52 kt sprint, 26 kt cruise
Endurance/range: high speed range over 1,500 nm

Payload: includes a range of unmanned systems including 11 m MCM RHIB, VTOL UAV such as Fire Scout, Remus 100 and Kingfish UUVs. plus manned special operations vehicles
Propulsion: 4 x 1,650 hp CAT C30 diesel engines
Notes: Stiletto Maritime Operations Center (MOC) acts as a mother ship for unmanned systems, delivering critical capabilities down range quickly, significantly reducing human risk and time on target.

Mistral/Magneto

Weight: 14,600 kg full load displacement
Length: 14.6 m
Speed: more than 30 kt at full load displacement
Endurance/range: 900 nm at 20 kt and full load
Payload: 4,082 kg at full load



Propulsion: 1,006 hp diesel
Notes: Optionally manned vessel offering remote or autonomous control including control of several unmanned Mistrals from one manned version. Can handle palletised cargo, launch and recover other unmanned and towed assets.

Naval Surface Warfare Center (US)

Modular Unmanned Surface Craft Littoral

Weight: 38.55 kg
Length: 1.83 m
X-Class man-portable USV platform for riverine combatant craft support to employ as a water-borne "point man" to increase situational awareness during operations on

inland waterways. It supports Navy Expeditionary Combat Command (NECC) requirements and is capable of carrying different sensors and payloads to provide a variety of capabilities such as intelligence, surveillance, and reconnaissance (ISR) and threat detection.

Njordworks Inc

Pioneer

Weight: 7 to 10 kg
Length: 1.07 m
Speed: 2.8 kt
Endurance: 20 to 60 minutes depending on throttle usage and payload power consumption

Payload: 3 kg, can support a wide range of lightweight TV and IR video cameras, stills cameras, imaging and hydrographic sonars, water quality sensors
Propulsion: 12V/7Ah LiFePO4 battery powering an airscrew
Notes: Small, very shallow draft airboat designed to get into confined spaces with difficult access for a wide variety of missions.

OceanServer Technology Inc

Iver 2

Weight: 20.4 to 29.5 kg
Length: 1.27 to 1.78 m
Speed: 1 to 4 kt
Endurance: 8 to 14 hours at 2.5 kt
Payload: Wide range of side scan, interferometric co-registered sonars, Doppler velocity logs, altimeters, bottom

tracking and current profiling sonars, conductivity and temperature sensors, sound velocity probe, stills and video cameras.
Propulsion: 48V servo controlled DC motor with 3-blade cast bronze propeller
Notes: family of low-cost AUVs for a variety of missions in maritime environments including lakes, reservoirs, rivers, and estuaries.

Iver 3

Weight: less than 38.55 kg
Length: 1.524 to 2.159 m
Speed: 1 to 4 kt
Endurance: 8 to 14 hours at 2.5 kt depending on configuration
Diving depth: 100 m

Payload: Sensor options include dual frequency side scan sonars such as the high definition Marine Sonic Sea Scan, L-3 Klein UUV-3500 and EdgeTech 2205, multi-beam sonars such as the Imagenex Delta T, CT and sound velocity sensors.
Propulsion: swappable 800-1200 Wh rechargeable Li-ion battery pack, driving 48V servo controlled DC motor with 3-blade cast bronze propeller
Notes: Iver 3 is an "affordable" work class AUV with intuitive mission planner.

Iver 3 Nano

Weight: 17.7 kg
Length: 1.651 m
Speed: 1 to 4 kt

Endurance: 6 to 10 hours at 2.5 kt survey speed depending on conditions
Diving depth: 60 m
Payload: Side scan sonar such as Tritech StarFish 452
Propulsion: 356 Wh rechargeable Li-ion battery pack, 36V servo controlled brushless DC motor with cast bronze propeller
Notes: Lightweight AUV designed for imaging missions in coastal waters, target reacquisition an identification by ROVs and divers.

Office of Naval Research (ONR)

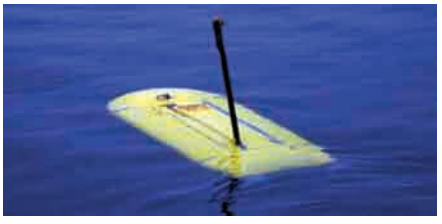
Large Displacement Unmanned Underwater Vehicle (LDUUV)

Endurance: More than 70 days
Notes: LDUUV is a programme to develop a pier-launched and recovered UUV (without the need for ship-launch or recovery) with the capability to transit in the open ocean

and conduct over-the-horizon missions in littoral waters. LDUUV missions include Intelligence Preparation of the Environment (IPOE), Anti-Submarine Warfare (ASW), Intelligence, Surveillance and Reconnaissance (ISR), and offensive operations.

Razor

Length: 1.676 m
Endurance: 6 to 20 hours on 1 to 3 batteries
Diving depth: 100 m



Payload: 76.2 cm mast with camera, GPS, comms; imaging sonar and subsurface camera on tilt mount
Propulsion: Up to 3 1.5 kW field replaceable tolerant lithium batteries
Notes: Razor UUV can be remotely operated or autonomous in a variety of harbour defence missions such as defence against combat swimmers, bottom surveys, hull and pier inspections, UUV sentry applications.

XRay

Speed: 1 to 3 kt
Endurance/range: up to 6 months/1,200 to 1,500 km
Payload: Passive sensors including sonar to track quiet conventionally powered submarines
Propulsion: buoyancy change pump

Notes: Liberdade is a project to develop a family of underwater gliders for the US Navy's Persistent Littoral Undersea Surveillance Network (PLUSNet) system of semi-autonomous controlled mobile assets. XRay is the latest prototype, a flying-wing-style glider whose large size is an advantage in terms of hydrodynamic efficiency and space for energy storage and payload.

ZRAy

Span: 6 m
Endurance/range: 1 month, 1,000 km
Payload: port leading edge 16 hydrophone array, starboard leading edge 11 hydrophone array, wideband acoustic sensors in nose and tail
Propulsion: buoyancy change pump
Notes: Large blended wing-body glider

AUV developed with ONR funding by the Scripps Institute of Oceanography, the University of Washington's Applied Physics Lab and the US Navy Space and Naval Warfare Systems Center Pacific.

Shipboard Autonomous Firefighting Robot

SAFFiR is a Naval Research Laboratory programme to develop a humanoid autonomous robot capable of finding and suppressing shipboard fires and working seamlessly with human fire fighters. It is a key component of a candidate Innovative Naval Prototype programme – Damage Control Technologies for the 21st Century. Parallel actuated biped with linear actuators in a bio-inspired geometry and 24 degrees of freedom. Capable of omni-directional walking, balancing in sea state conditions and traversing obstacles, manipulating fire suppressors, use existing thermal shielding equipment, autonomous navigation of shipboard environment with appropriate sensor suite.

Pennsylvania State University

Seahorse

Weight: 4,536 kg
Length: 8.69 m
Speed: 4 to 6 kt sustained
Endurance/range: 500 nm at 4 kt cruise
Payload: Marine Sonics dual frequency side scan sonar, Seabird SBE-31 CTD, Paroscientific precision pressure sensor, RDI Acoustic Doppler Current Profiler (ADCP)

Propulsion: 9,126 alkaline batteries providing energy for 5 hp Lynx Motion synchronous electric motor with Advanced Digital System three-phase inverter driving a ducted pump jet
Notes: Designed to collect high quality environmental data with precision location in littoral regions. Reliability, ease of maintenance and cost effectiveness and operation from US Navy T-AGS 60 class oceanographic vessels.

Sea Maverick

Length: 9.14 m Speed: 15 kt approx submerged Diving depth: 1,000 m Propulsion: Electric Notes: Research AUV designed and built by the Applied Research

Laboratory at Pennsylvania State University in partnership with Key West-based JIATF South, the US Navy and Office of the Secretary of Defense Rapid Release of Technology Office. Sea Maverick is designed to be environmentally friendly, detect and monitor highly mobile objects and relay that information to multiple recipients in a timely manner.

Polish Naval Academy in Gydnia/Gdansk University of Technology

Edredon

Weight: 2,000 kg
Length: 5.7 m
Speed: 30 kt max
Endurance/range: 8 to 130 hours subject to speed, sea state and load/up to 20 km

Payload: 1,000 kg, day/night cameras with laser rangefinder, panoramic camera, sonar, chemical and meteorological sensors
Notes: Experimental USV based on hybrid rubber/fabric hulled boat developed for coastal patrol, port security, environmental protection and search and rescue missions.

Qinetiq North America

Blackfish

Weight: 470 kg dry, 515 kg wet
Length: 3.22 m
Speed: approx 45 kt transit, -4 to 4 kt tracking

Endurance: at least 1 hour/1 km from control antennas
Payload: up to 150 kg, pan-tilt-zoom video camera, high-resolution 2-D sonar, underwater video camera
Propulsion: Battery electric
Notes: Maritime force protection USV for operation in ports and harbours. Optional 2D high-resolution sonar and underwater video camera enable location, classification and pursuit of underwater threats such as swimmers and divers.

Sea Scout

Length: 91.44 cm (36 in)
Speed: more than 15 kt
Diving depth: 200 m
Payload: Power and signal connections for two separate payload sensors are provided, a wide range of payload sensors can be accommodated. Additionally, the tail section admits towed payloads.

Propulsion: 230 Wh battery capacity, flooded electric motor driving ducted propulsor
Notes: Lightweight general purpose and anti-submarine warfare UUV designed for deployment from A-size aircraft sonobuoy launchers and for hand launch and recovery from small boats.

Rafael

Protector

Weight: 4,000 kg
Length: 9 - 11 m
Speed: at least 38 kt
Payload: Radar, Toplite electro-optical

sensor turret, Mini-Typhoon stabilised gun system capable of operating a variety of small calibre machine guns
Notes: Protector is a family of small USVs with remote and autonomous operations capabilities. Plug and play modules enable configuration for anti-terror force protection, ISR, ASW, ASuW, mine warfare and mine countermeasures, EW, maritime/port security missions.

Saab

AUV 62

Weight: 600 to 1,500 kg depending on configuration
Length: 4, 7 or 10 m depending on configuration
Speed: 0 to 20 kt
Diving depth: around 500 m
Payload: sonar that provides better than 4 x 4 cm resolution, 2 x 200 m swath width for high-resolution or 2 x 400 m rapid area assessment missions and respective 2.5 or 20 km2/hour coverage rates
Propulsion: Rechargeable batteries and ducted propulsor
Notes: Submarine, ship or shore launched AUV62-MR is designed to operate autonomously and perform long-term mine reconnaissance missions with high speed of advance and advanced information gathering independently of dedicated platforms.

Double Eagle MkII

Weight: approx 360 kg in air
Length: 2.2 m
Speed: more than 6 kt forward, 0.7 kt lateral, 0.4 kt vertical, 6 kt ascent/descent
Diving depth: 500 m
Payload: Colour CCD camera, sonar options include electronic scanning sonar on 0-90° tilting mount to enable placing of mine disposal charge in zero visibility.
Propulsion: Two 5 kW brushless motors. Approx. 2,500 N forward thrust. Six 0.4 kW brushless motors.
Notes: Mine countermeasures ROV designed for operation from MCM vessels, craft of opportunity or the shore. Base configurations are for mine reconnaissance - both remotely controlled and autonomous - and mine disposal.

Double Eagle MkIII

Weight: approx 500 kg
Length: 3 m
Speed: 0 to more than 7 kt
Payload: More than 250 kg, mine hunting sonars, mine disposal charge

Propulsion: Four 7 kW (10 hp) brushless motors. Approx. 7,500 N forward thrust. Six 400W brushless motors.
Notes: Mine countermeasures ROV designed for operation from MCM vessels, craft of opportunity or the shore. Base configurations are for mine reconnaissance - both remotely controlled and autonomous - and mine disposal.

Sandia National Laboratories Intelligent Systems

Volant

Volant is a conceptual single unmanned system capable of flying, swimming, driving, and hopping across a variety of terrains and obstacles conceived by Sandia National Laboratories' Intelligent Systems,

Robotics, & Cybernetics (ISRC) organisation. A simulation shows a UAV-towed glider that lands in water and sheds its wings to reveal a swimming AUV, which in turn sheds flippers to become a UGV that crawls up a beach to reconnoitre a shore facility. Testing shows that the concept could soon be reality, according to ISRC.

Searobotics

Catamaran 11 m open water USV

Speed: 9 kt max, 5 kt average
Endurance: up to 60 days, operates through sea state 5 for up to 30 days
Payload: Acoustic Doppler Current Profiler (ADCP) in port hull

Propulsion: diesel electric hybrid
Notes: Delivered to the University of Rhode Island in 2013 to support the Surveying Coastal Ocean Autonomous Profile (SCOAP) mission in which it is intended to perform a variety of data acquisition tasks to support material transport investigations as well as multidisciplinary studies for coastal oceanographers.

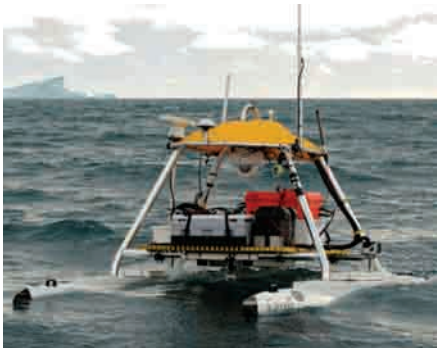
Catamaran 2.0 - 4.0 collapsible USV

Length: 2 to 4 m
Notes: A range of compact, collapsible catamaran USVs designed to offer all the features of a larger USV in vehicles compact

enough to ship in a pallet crate and simple enough for assembly on sight from lightweight parts.

Catamaran 4.0 m general purpose USV

Length: 4 m
Payload: Vehicle can be outfitted with a survey-grade echo sounder, side-scan sonar, and multi-beam sonar or reconfigured with additional sensors for survey-specific requirements.



Notes: Small but capable USV designed for numerous applications specific designs, highly manoeuvrable, high efficiency hulls.

Catamaran 5.7 m general purpose USV

Length: 5.7 m
Speed: more than 5 m/sec
Payload: 350 kg on substantial payload deck
Propulsion: All electric or diesel electric hybrid
Notes: General purpose USV, an example of which was delivered to NATO's Center for Marine Research and Experimentation

(CMRE) in 2013. It will be used to improve payload capacity and efficiency of the fully autonomous mine neutralization system. System can ship worldwide in a standard 20 ft container, trailer doubles as a shipping cart.

High Speed USVs

Length: 1.5, 5, 7 and 9 m
Notes: A family of high speed manned and unmanned surface vessels is offered for security, surveillance, target and test applications.

Singapore Technologies Electronics Ltd

Venus

Length: 9 m and 16 m versions available
Payload: Up to 1.5 tons including Thales Underwater Systems towed synthetic aperture sonar, ECA expendable mine

disposal systems, Oto Melara remote weapon station, dipping sonar for ASW
Notes: Modular customisable USV platform for multiple missions

Swiftships

Anaconda

Weight: 11,485 kg
Length: 10.7 m
Speed: more than 50 kt
Endurance/range: more than 200 nm at 35 kt
Payload: A wide range of sensors and

effectors can be integrated, features a bow ramp for cargo or personnel, removable seating
Propulsion: 2 x 560 bhp diesel engines, 2 Rolls Royce FF-series water jets
Notes: Armoured riverine/littoral patrol boat being converted in cooperation with the University of Louisiana at Lafayette for unmanned operations, designed to be fully operational in Sea State 2 and survive in Sea State 4.

Teledyne Webb Research

G2 Slocum Glider

Weight: 54 kg
Length: 1.5 m
Speed: 0.68 kt average
Endurance/range: 4 to 8 months/2,158 to 3,238 nm on lithium batteries, 15 to 50 days/324 to 809 nm on alkaline batteries
Payload: 6 litre payload bay can accommodate a wide range of sensors including acoustic bioprobe, acoustic Doppler current profiler, acoustic mammal detector, bathyphotometer, beam attenuation meter, pumped CTD, hydrophones, optical backscatter, optical fluorometer,optical attenuation meter, optical fluorometer, oxygen sensor, PAR, radiometer, algal spectrophotometer, turbulence meter.
Propulsion: Electric buoyancy change pump
Notes: Buoyancy driven AUV for ocean research and monitoring, creation of sound speed profiles etc.

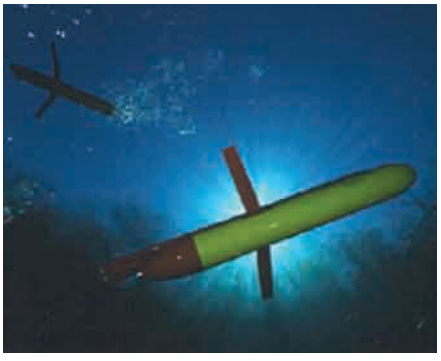
Electric Glider

Weight: 52 kg
Length: 1.5 m
Speed: 0.77 kt horizontal average
Endurance/range: 30 days/810 nm depending on measurement and communication
Diving depth: 4 to 200 m, 1,000 m option available

Payload: Flexible payload bay enables integration of a range of devices including Conductivity, Temperature and Depth (CTD) sensors
Propulsion: Alkaline battery powered buoyancy change pump
Notes: Long endurance buoyancy driven glider, sawtooth profile progress common to all gliders optimal for vertical and horizontal observations in water column.

Thermal Glider

Weight: 52 kg
Length: 1.5 m

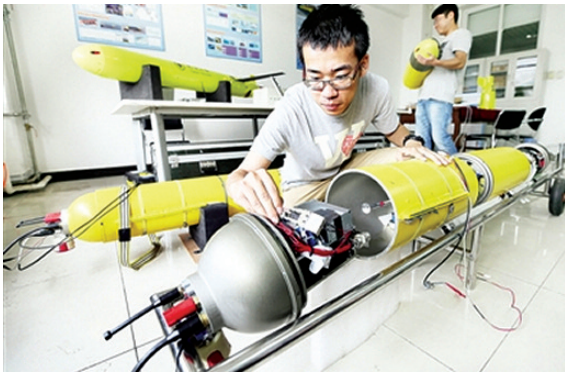


Speed: 0.77 kt horizontal average
Endurance/range: 3 to 5 years/40,000 km projected
Diving depth: 1,200 m
Payload: Conductivity Temperature and Depth (CTD) sensor
Propulsion: Buoyancy change pump driven by environmental thermal engine
Notes: Environmentally powered, buoyancy driven glider for long-term environmental monitoring. Slocum Thermal Glider is comprised of one main hull section, a solid machined nose dome, a wet section located aft in addition to two thermal tubes located below the hull.

Tianjin University

Haiyan (Petrel)

Weight: 70 kg
Length: 1.8 m
Speed: about 0.5 kt probable
Endurance/range: 30 days/1,000 km
Diving depth: 1,500 m
Payload: 5 kg, acoustic and bio-optical instruments for oceanographic observation



Propulsion: Electrically powered buoyancy change pump
Notes: Petrel II is China's first underwater glider, which passed a 1,500 m deep water test in the northern part of the South China Sea, establishing Chinese range, depth and endurance records and bypassing imposed technology restrictions.

Thales

ASEMAR

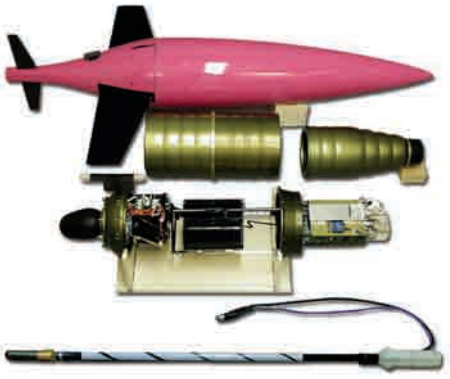
Study for the design of a surveillance-based AUV for maritime security operations. This project, signed with the Maritime Cluster initiative in the French region of Brittany, involves two industrial partners (Thales and ECA) and four educational institutions in France. It is part

of a series of experiments undertaken in conjunction with the NATO Undersea Research Center (NURC) and the DUBM-44 programme for developing high-level AUV payloads. Thales is responsible for developing the sonar system, as well as the autonomous decision-making capability and the high-resolution synthetic aperture side-scan sonar.

University of Washington

Seaglider

Weight: 52 kg dry
Length: 1.8 m
Speed: 0.5 kt



Endurance/range: 2,484 nm (650 dives to 1,000 m)
Diving depth: 1,000 m
Payload: Sea Bird CTD and dissolved oxygen sensor, WET Labs fluorometer-optical backscatter sensor, variable sample rate by sensor and depth range
Propulsion: Lithium primary batteries in 24V and 10V packs, 10 MJ total, driving buoyancy change pump
Notes: Glider developed for physical, chemical, and biological oceanography, tactical oceanography, maritime reconnaissance, communication gateway, navigation aid applications.

Virginia Tech

Cyro

Weight: 77.11 kg
Length: 1.701 m
Endurance: measured in months
Propulsion: Pulsating propulsion technique mimics that of jellyfish, powered by rechargeable nickel metal hydride battery

Notes: US Navy funded biomimetic AUV project intended to develop self-powering autonomous robots for surveillance, environmental monitoring, sea life observation, mapping of ocean floors and currents.

INDEX TO ADVERTISERS

ON THE COVER: Naval robots are normally supposed to swim on the surface or under water. This specimen form Eca adds the supreme sophistication of turning itself into an underwater land robot as it can crawl on the seabed thanks to its tracks.

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233 Hollywood Road, Sheung Wan, Hong Kong.
Tel: (852) 2815 9111, Fax: (852) 2815 1933

Editor-in-Chief: Eric H. Biass
Regular Contributors: Roy Braybrook, Paolo Valpolini, Peter Donaldson, Wesley Fox
Chairman: J.S. Uberoi
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Advertising Sales Offices
- AUSTRIA, BENELUX, SWITZERLAND
Cornelius W. Bontje
Ph: +41 55 216 17 81, cornelius.bontje@armada.ch
- FRANCE
Promotion et Motivation, Odile Orbec
Ph: +33 1 41 43 83 00, o.orbec@pema-group.com
- GERMANY
Sam Baird Ph: +44 1883 715 697,
sam@whitehillmedia.com
- ITALY, NORDIC COUNTRIES
Emanuela Castagnetti-Gillberg
Ph: +46 31 799 9028, egillberg@glocalnet.net
- SPAIN
Vía Exclusivas, Macarena Fdez. de Grado
Ph: +34 91 448 76 22, macarena@viaexclusivas.com
- UNITED KINGDOM
Zena Coupé
Ph: +44 1923 852537, zena@expomedia.biz
- RUSSIA
Alla Butova, NOVO-Media Ltd,
Ph: (7 3832) 180 885 Mobile: (7 960) 783 6653
Email: alla@mediatransasia.com
- EASTERN USA – EAST OF THE MISSISSIPPI RIVER
Margie Brown, Ph: (540) 341 7581,
margiespub@rcn.com
- WESTERN USA – WEST OF THE MISSISSIPPI RIVER
Diane Obright, Ph: (858) 759 3557,
blackrockmediainc@icloud.com
- ALL OTHER COUNTRIES
Vishal Mehta, Tel: (91) 124 4759625, Mob: (91) 99 999 85425
E-Mail: vishal@mediatransasia.com
Jakhongir Djalmetov, Mobile: (91) 98 995 50162
E-Mail: joha@mtil.biz

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